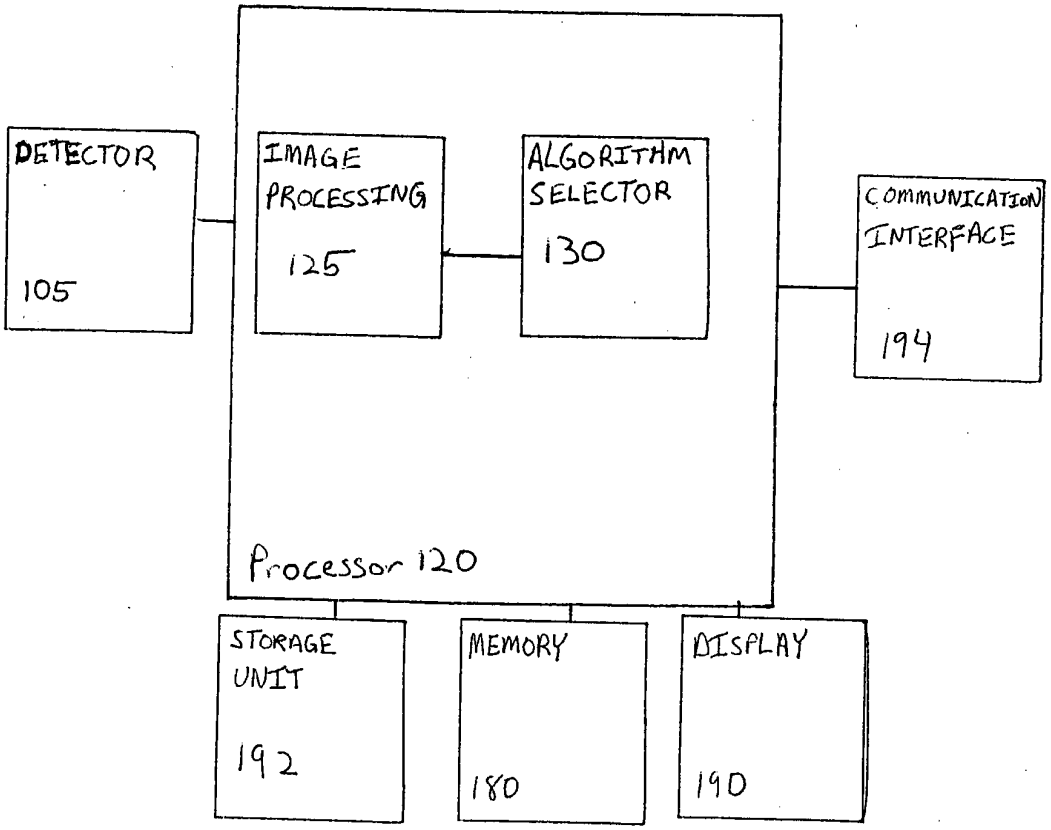
FIG 1


DETECTOR
105
IMAGE PROCESSING
125
ALGORITHM SELECTOR
130
COMMUNICATION INTERFACE
194
Processor 120
STORAGE UNIT
192
MEMORY
180
DISPLAY
190

100

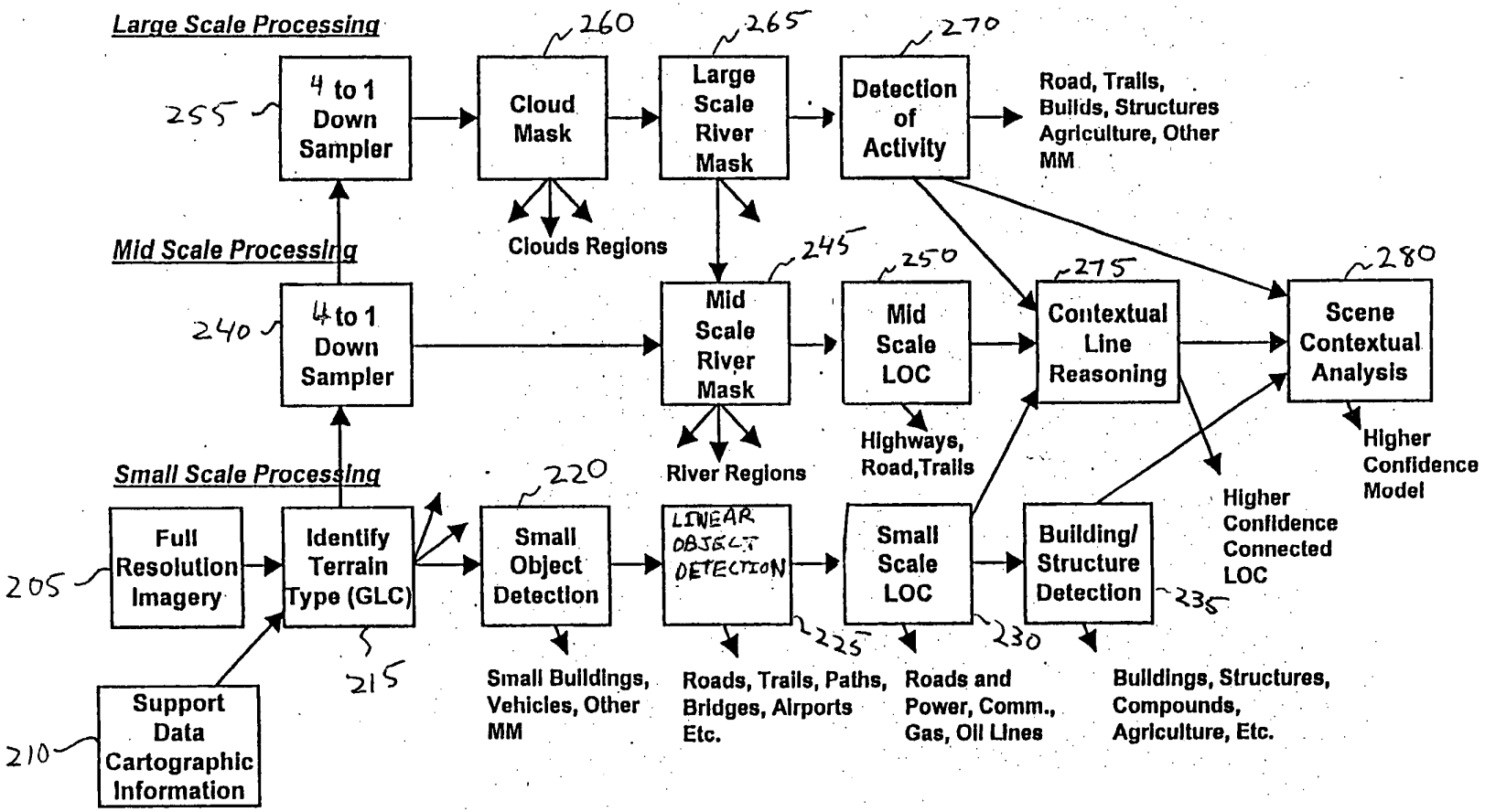

Large Scale Processing
Mid Scale Processing
Small Scale Processing
255
4 to 1 Down Sampler
260
Cloud Mask
Clouds Regions
265
Large Scale River Mask
270
Detection of Activity
Road, Trails, Builds, Structures Agriculture, Other MM
240
4 to 1 Down Sampler
245
Mid Scale River Mask
River Regions
250
Mid Scale LOC
Highways, Road,Trails
275
Contextual Line Reasoning
280
Scene Contextual Analysis
Higher Confidence Model
Higher Confidence Connected LOC
205
Full Resolution Imagery
Identify Terrain Type (GLC)
215
220
Small Object Detection
Small Buildings, Vehicles, Other MM
LINEAR OBJECT DETECTION
225
Roads, Trails, Paths, Bridges, Airports Etc.
Small Scale LOC
230
Roads and Power, Comm., Gas, Oil Lines
Building/ Structure Detection
235
Buildings, Structures, Compounds, Agriculture, Etc.
210
Support Data Cartographic Information

FIG 2

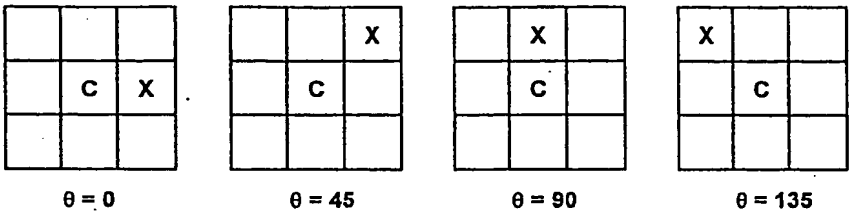


FIG 3

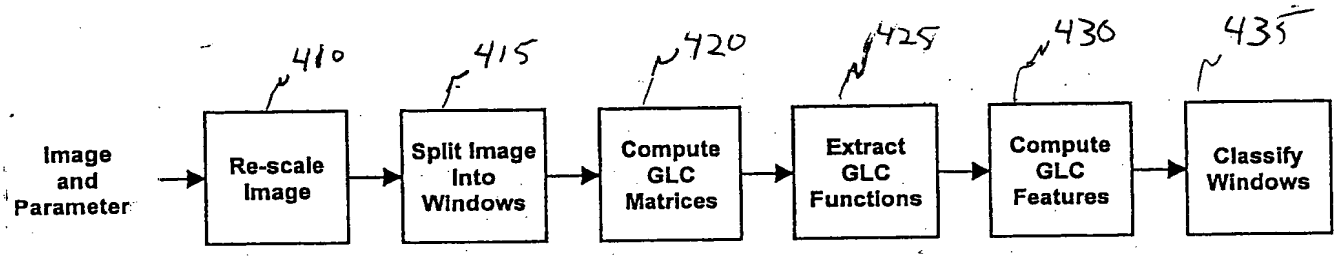


FIG. 4

Energy

$$En = \sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\left(G(i,j)\right)^2$$

Entropy

$$Et = \sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\left(G(i,j)\log(G(i,j))\right)$$

Contrast

$$Ct = \sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\left(G(i,j)\times(i-j)^2\right)$$

Inverse_Difference_Moment

$$En = \sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\frac{G(i,j)}{1+(i-j)^2}$$

Correlation

$$Cr = \sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\frac{i\times j\times G(i,j)-\mu_x\times\mu_y}{\sigma_x\times\sigma_y}$$

FIG 5

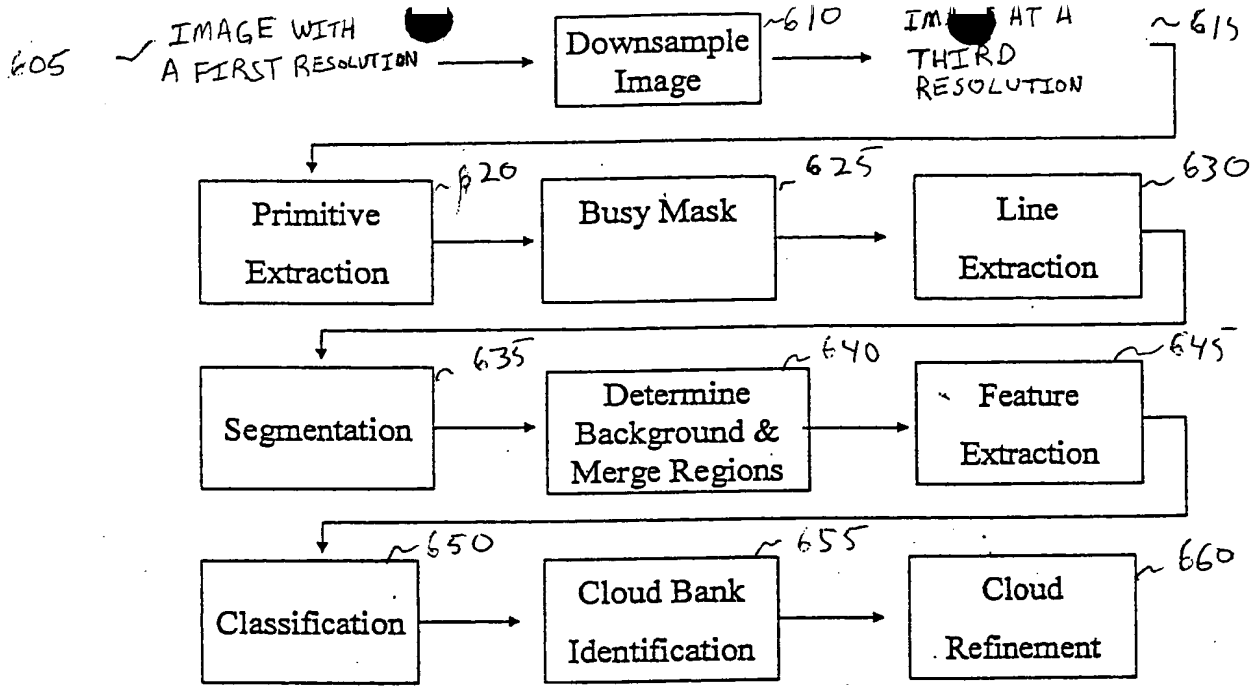


FIG 6

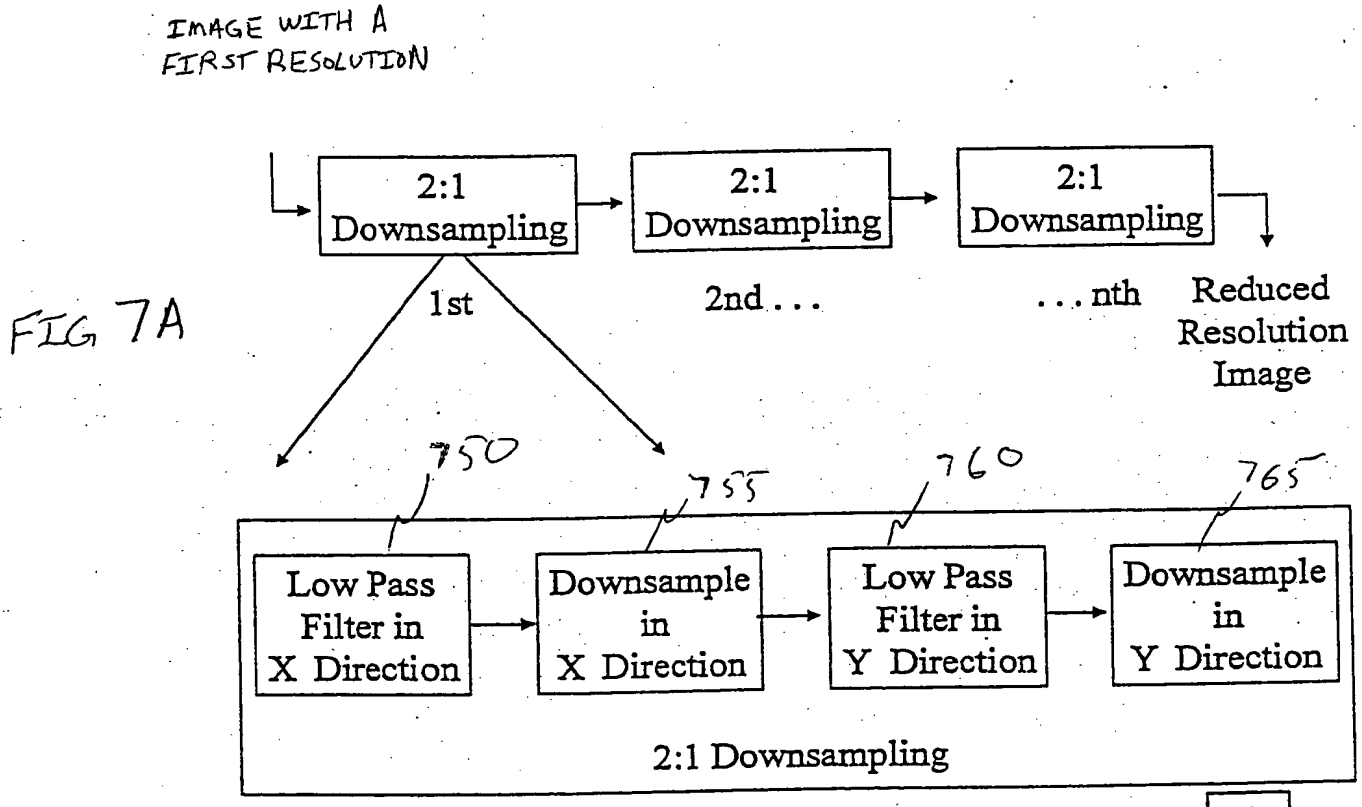


FIG 7A

1	4	6	4	1
1	16	24	16	1
1	24	36	24	1
1	16	24	16	1
1	4	6	4	1

Full 6 by 6 Convolution Filter

FIG 7B

1	4	6	4	1

X Direction Filter

FIG 7C

1
4
6
4
1

Y Direction Filter

FIG 7D

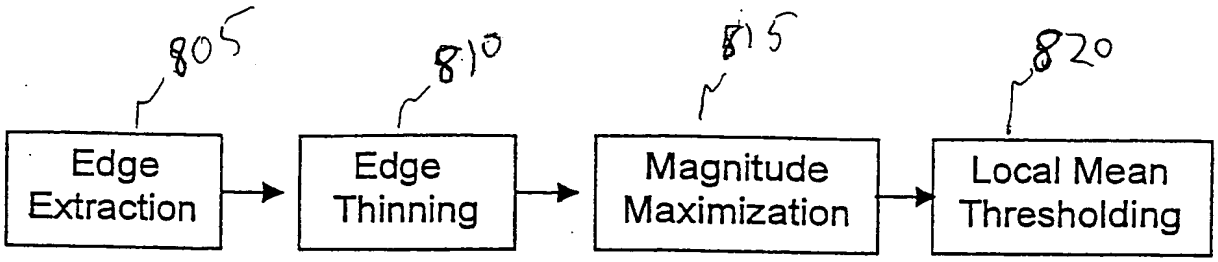


FIG 8

-1 -2 -1 0 0 0 1 2 1	-1 0 1 -2 0 2 -1 0 1	4 5 6 3 * 7 2 1 8
Horizontal Component Template	Vertical Component Template	Directional Mapping

D_x = convolution of the vertical template with the image

D_y = convolution of the horizontal template with the image

Sobel Magnitude = $(D_x^2 + D_y^2)^{1/2}$

Sobel Direction = Arctan (D_y / D_x) mapped to 8 directions

FIG 9A

FIG 9B

Directions 3 & 7	Directions 1 & 5	Directions 2 & 6	Directions 4 & 8
OOOOO	OXXXO	OOOXO	OXOOO
XOOOX	OOXOO	OOOXX	XXOOO
XXCXX	OOCOO	OOCOO	OOCOO
XOOOX	OOXOO	XXOOO	OOOXX
OOOOO	OXXXO	OXOOO	OOOXO

C = Center pixel X = Non-zero pixel O = Don't care pixel

FIG 10

```
   XXX
  XXXXX
 XXXXX
XXXXX
 XXXXX
  XXXX
 XXXX
```

FIG 11A

```
  XXX
  XXX
 XXX
 XXX
XXX
XXX
XX
```

FIG 11B

X1X	X1X	XXO	OXX
XC1	1CX	1CX	XC1
OXX	XXO	X1X	X1X

1 = non-zero pixel, o = zero pixel, x = don't care

FIG 12

```
   XXX
  XXX
 XXX
 XXX
 XXX
 XXX
XX
```

FIG 13A

```
  XX
  XX
 XX
 XX
XX
XX
XX
```

FIG 13B

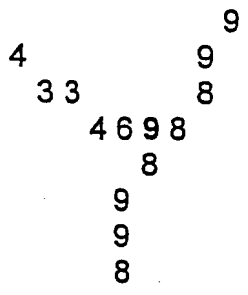


FIG 14A

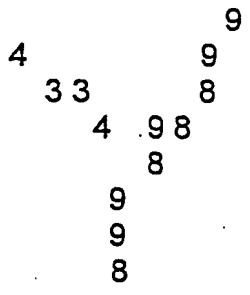


FIG 14B

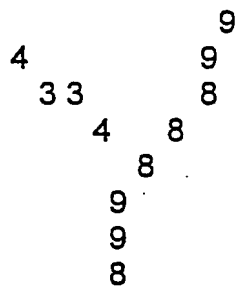


FIG 14C

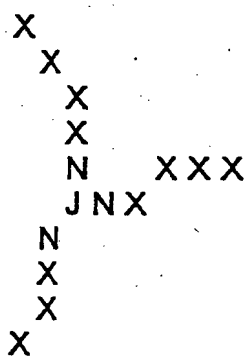


FIG 15A

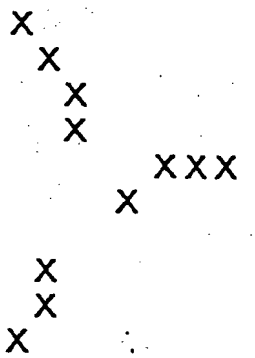


FIG 15B

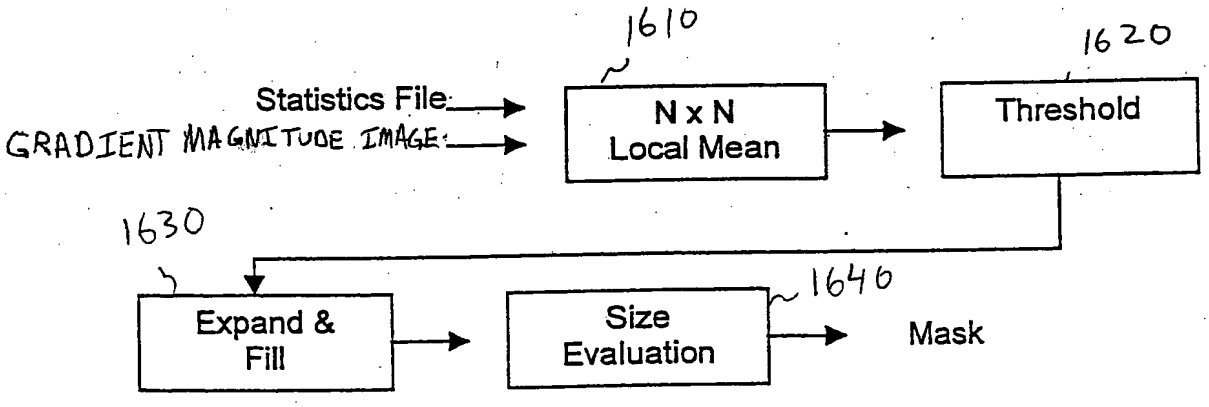


FIG 16

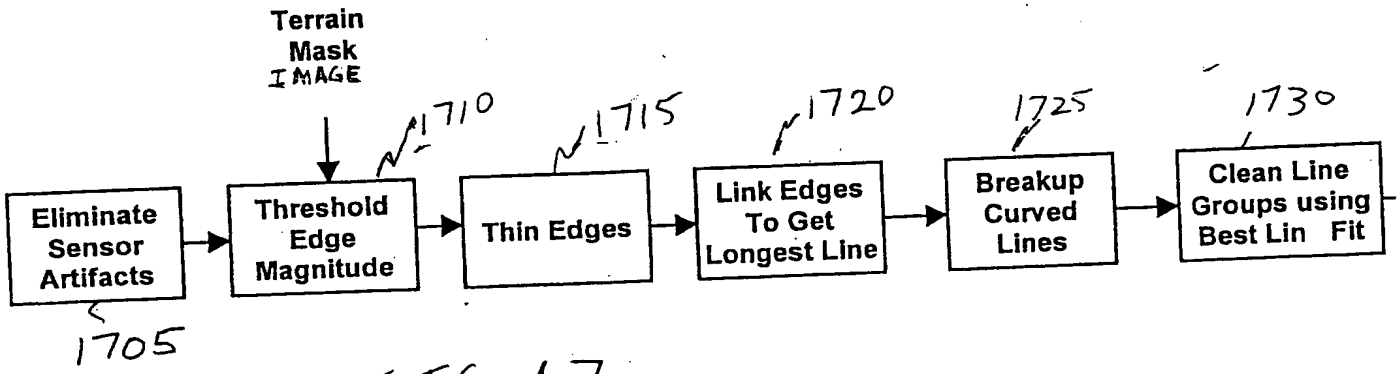
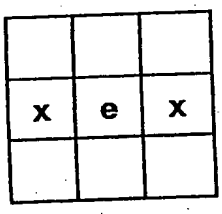
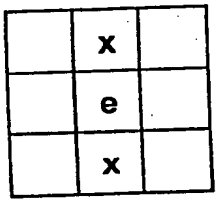


FIG 17



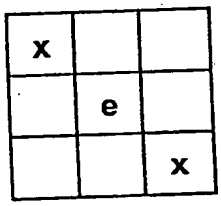
3 and 7

FIG 18A



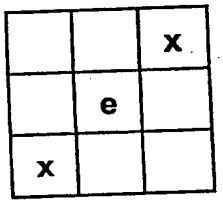
1 and 5

FIG 18B



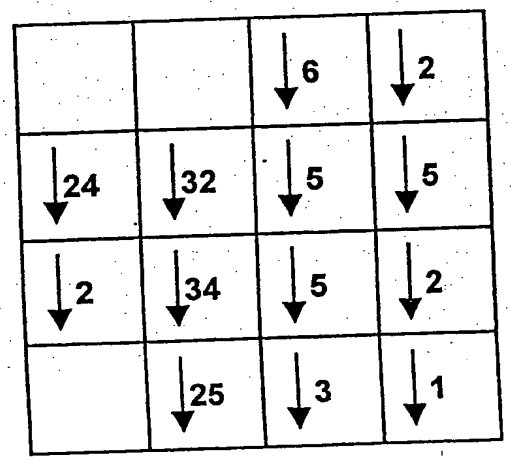
4 and 8

FIG 18C



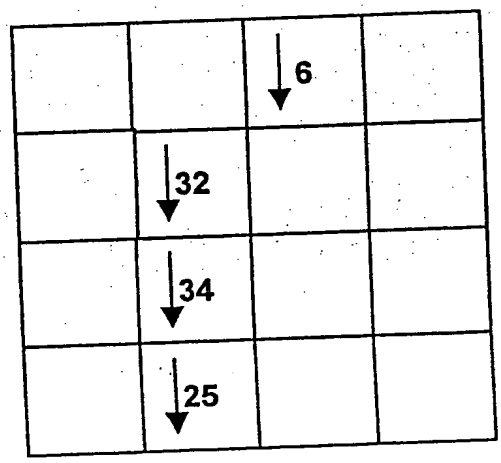
2 and 6

FIG 18D



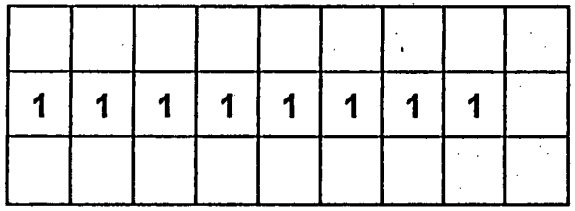
Edges Directions and Magnitudes

FIG 19A



Thinning Edges

FIG 19B



No Noise Present

FIG 20A

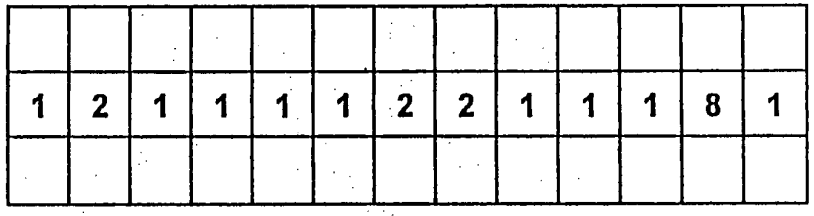
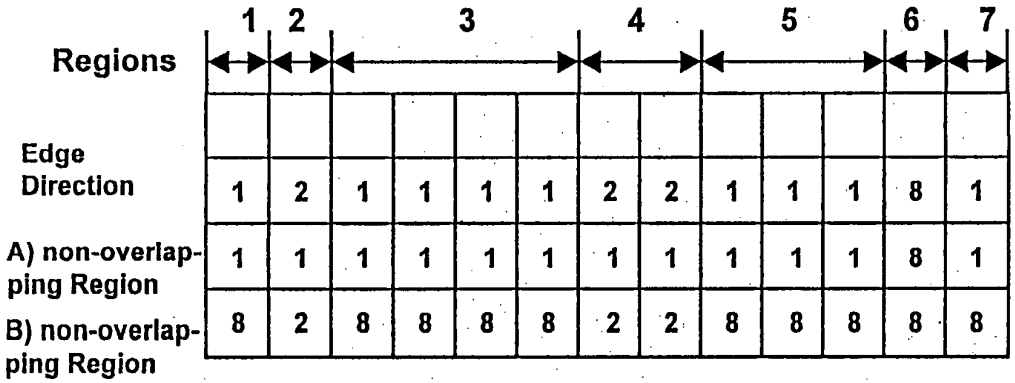


FIG 20B Noise Present



Direction 1 = direction 1 and direction 2

Direction 2 = direction 2 and direction 3

Direction 3 = direction 3 and direction 4

Direction 4 = direction 4 and direction 5

Direction 5 = direction 5 and direction 6

Direction 6 = direction 6 and direction 7

Direction 7 = direction 7 and direction 8

Direction 8 = direction 8 and direction 1

FIG 20C

FIG 21A

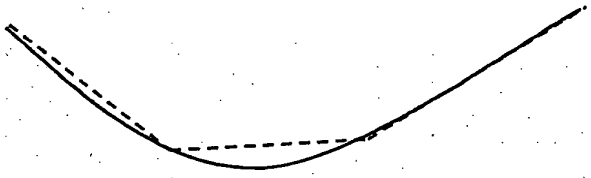


FIG 21B

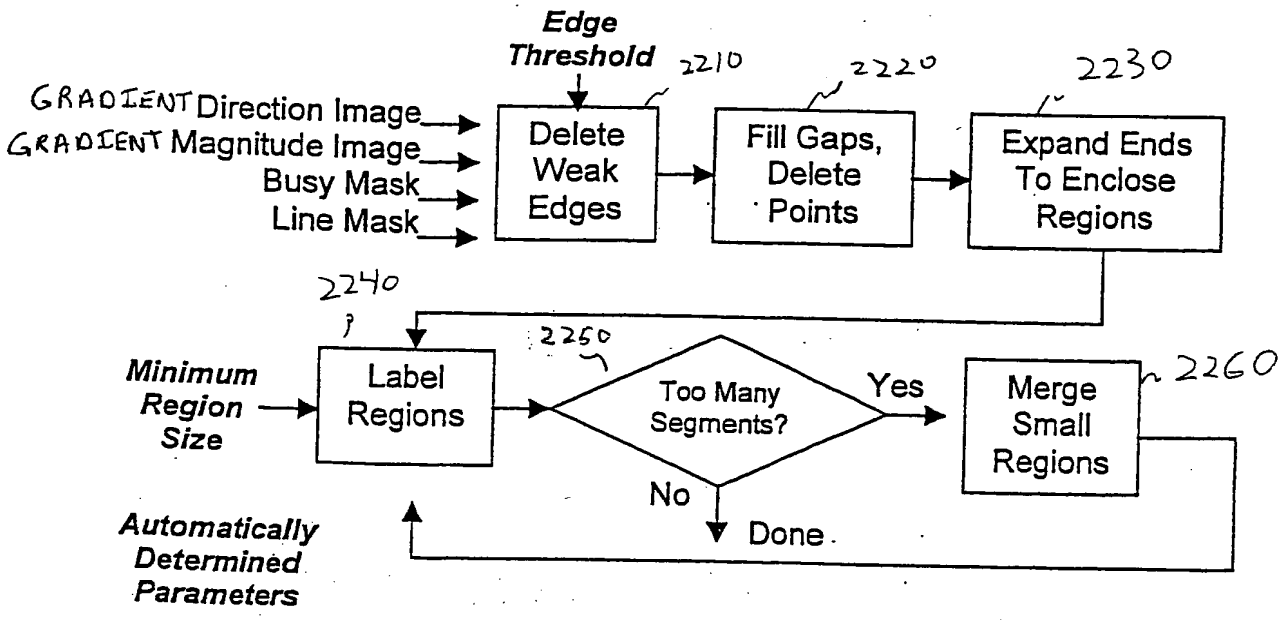


FIG 22

E E O	O E E	O E O	O E O
O C O	O C O	O C O	O C O
O E O	O E O	E E O	O E E

Templates for Vertical Point Gap

C = center pixel, value 1 E = pixel value 1 O = Zero pixel value

E O O	O O E	O O O	O O O
E C E	E C E	E C E	E C E
O O O	O O O	E O O	O O E

Templates for Horizontal Point Gap

FIG 23

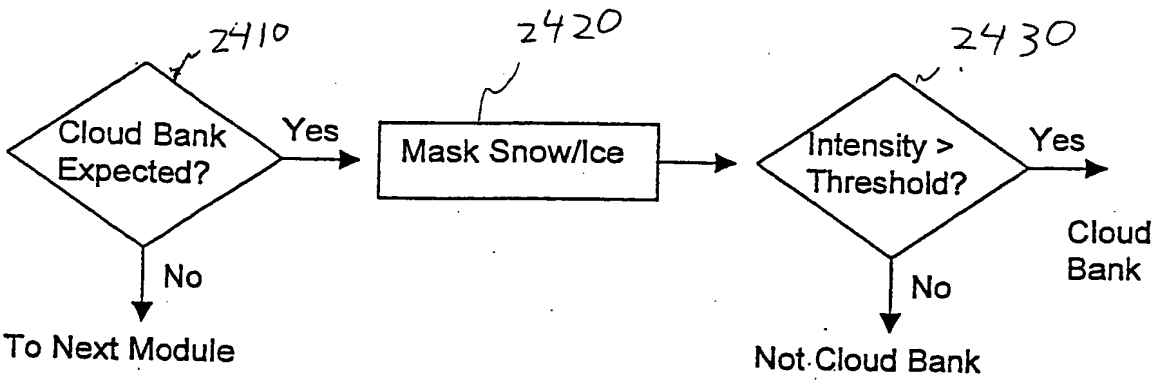

2410
Cloud Bank Expected?
Yes
No
To Next Module
2420
Mask Snow/Ice
2430
Intensity > Threshold?
Yes
Cloud Bank
No
Not Cloud Bank

FIG 24

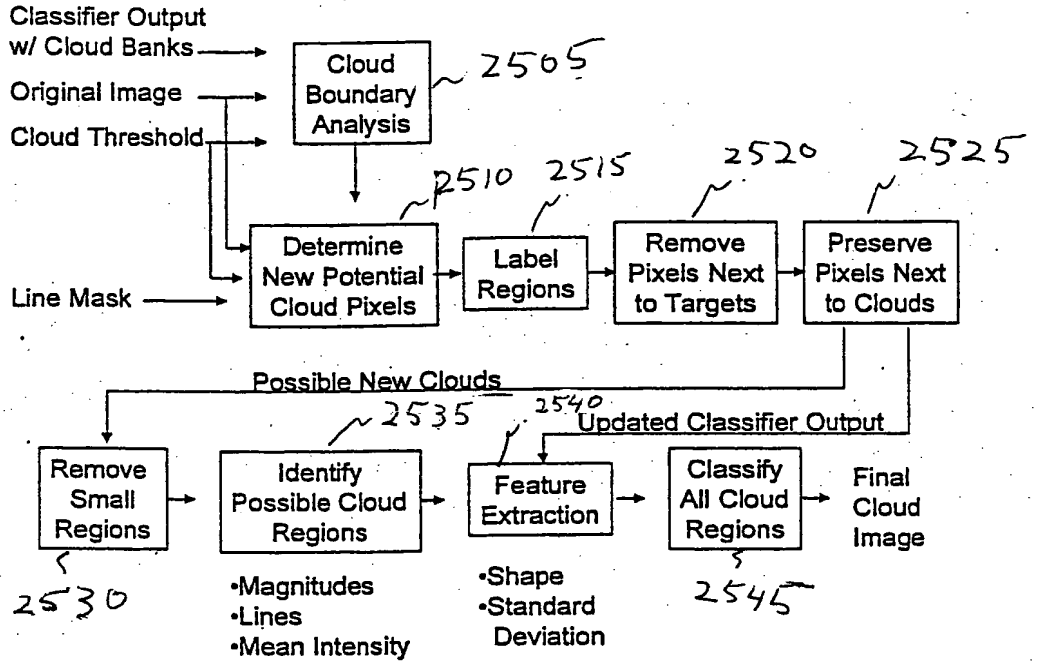

Classifier Output w/ Cloud Banks
Original Image
Cloud Threshold
Line Mask
Cloud Boundary Analysis
2505
Determine New Potential Cloud Pixels
2510
Label Regions
2515
Remove Pixels Next to Targets
2520
Preserve Pixels Next to Clouds
2525
Possible New Clouds
Updated Classifier Output
2535
2540
Remove Small Regions
2530
Identify Possible Cloud Regions
•Magnitudes
•Lines
•Mean Intensity
Feature Extraction
•Shape
•Standard Deviation
Classify All Cloud Regions
2545
Final Cloud Image

FIG 25

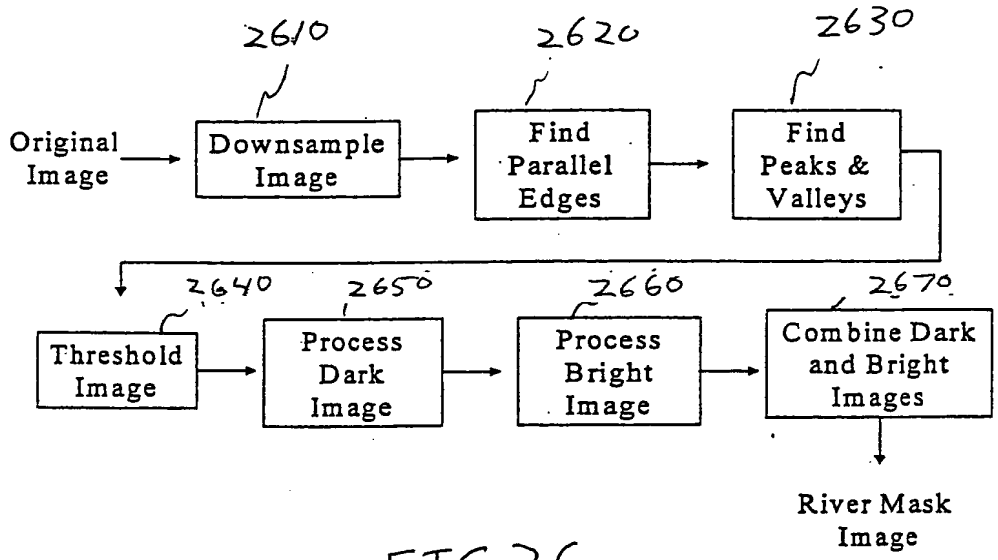

2610
2620
2630
Original Image
Downsample Image
Find Parallel Edges
Find Peaks & Valleys
2640
2650
2660
2670
Threshold Image
Process Dark Image
Process Bright Image
Combine Dark and Bright Images
River Mask Image

FIG 26

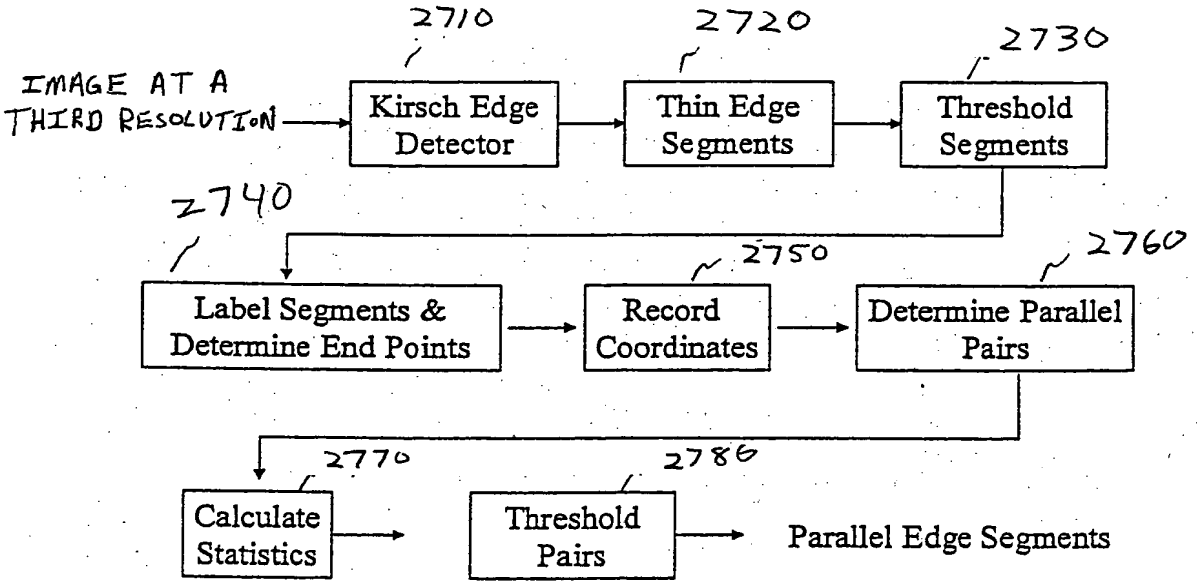

2710
2720
2730
IMAGE AT A THIRD RESOLUTION
Kirsch Edge Detector
Thin Edge Segments
Threshold Segments
2740
2750
2760
Label Segments & Determine End Points
Record Coordinates
Determine Parallel Pairs
2770
2780
Calculate Statistics
Threshold Pairs
Parallel Edge Segments

FIG 27

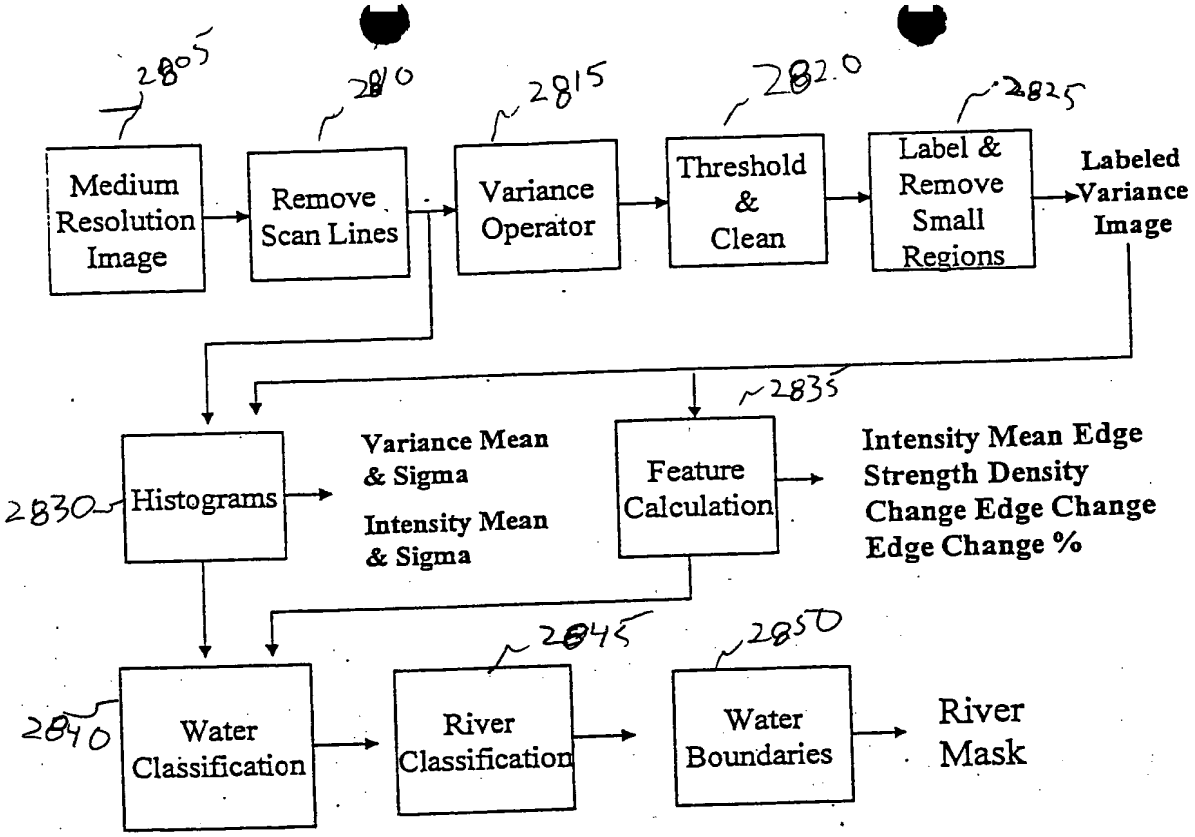


FIG 28

$a_{-1,-1}$	$a_{0,-1}$	$a_{1,-1}$
$a_{-1,0}$	$a_{0,0}$	$a_{1,0}$
$a_{-1,1}$	$a_{0,1}$	$a_{1,1}$

3by3 neighborhood

$$\sigma = \frac{1}{n}\sum_{j=-k}^{k}\sum_{i=-k}^{k}(a_{ij}-\mu)^2$$

where

$$\mu = \frac{1}{n}\sum_{i=-k}^{k}(a_{ij})$$

FIG 29B

For a 3by3 neighborhood k=1

FIG 29A

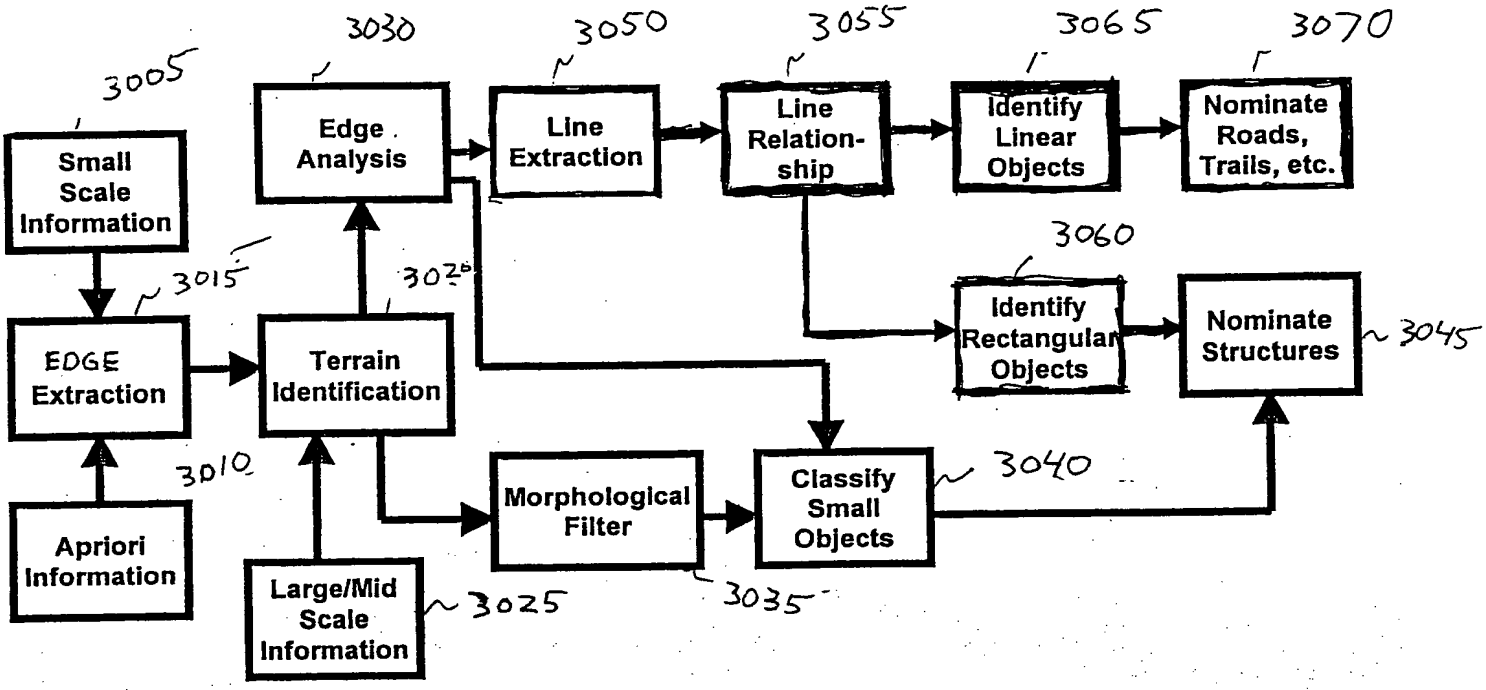

3005
Small Scale Information
3015
EDGE Extraction
3010
Apriori Information
3030
Edge Analysis
3020
Terrain Identification
Large/Mid Scale Information
3025
3050
Line Extraction
Morphological Filter
3035
3055
Line Relation-ship
Classify Small Objects
3040
3065
Identify Linear Objects
3070
Nominate Roads, Trails, etc.
3060
Identify Rectangular Objects
Nominate Structures
3045

FIG 30

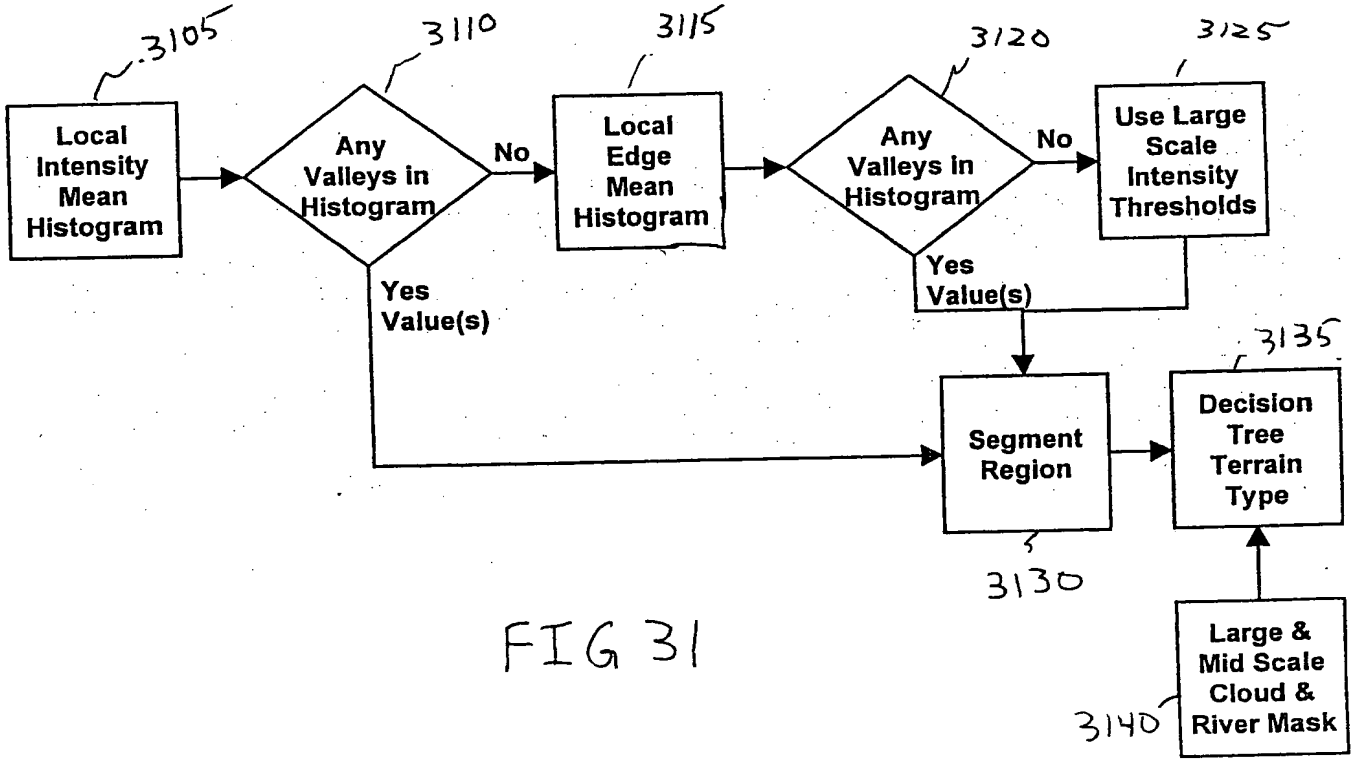

3105
Local Intensity Mean Histogram
3110
Any Valleys in Histogram
No
Yes
Value(s)
3115
Local Edge Mean Histogram
3120
Any Valleys in Histogram
No
Yes
Value(s)
3125
Use Large Scale Intensity Thresholds
3135
Segment Region
3130
Decision Tree Terrain Type
Large & Mid Scale Cloud & River Mask
3140

FIG 31

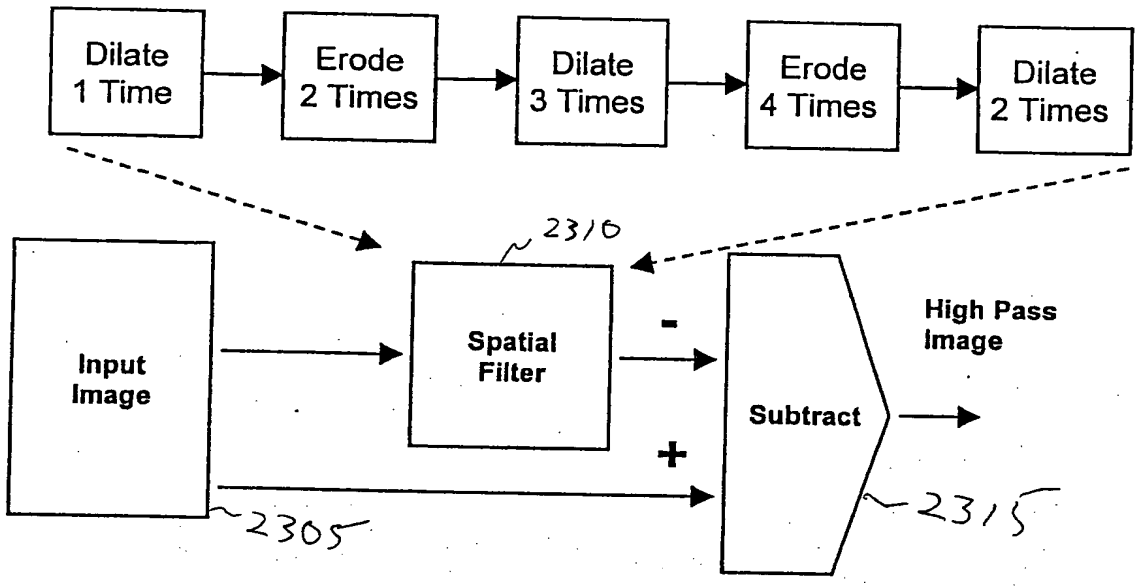


FIG 32

Input Image Pixels

a	b	c
d	e	f
g	h	i

⊕

Dilation Neighborhood

1	1	1
1	1	1
1	1	1

=

Input Image Pixels

a'	b'	c'
b'	e'	f'
g'	h'	i'

where e' = Maximum of { a, b, c, d, e, f, g, h, i }

FIG 33A

Input Image Pixels

a	b	c
d	e	f
g	h	i

⊖

Erosion Neighborhood

1	1	1
1	1	1
1	1	1

=

Input Image Pixels

a'	b'	c'
b'	e'	f'
g'	h'	i'

where e' = Minimum of { a, b, c, d, e, f, g, h, i }

FIG 33B

Horizontal	Vertical	Diagonal 1	Diagonal 2
1 1 1	-1 0 1	0 1 1	-1 -1 0
0 0 0	-1 0 1	-1 0 1	-1 0 1
-1 -1 -1	-1 0 1	-1 -1 0	0 1 1

FIG 34A

Gradient Sign	Horizontal	Vertical	Diagonal 1	Diagonal 2
	+ -	+ -	+ -	+ -
Direction	1 5	3 7	2 6	4 8

FIG 34B

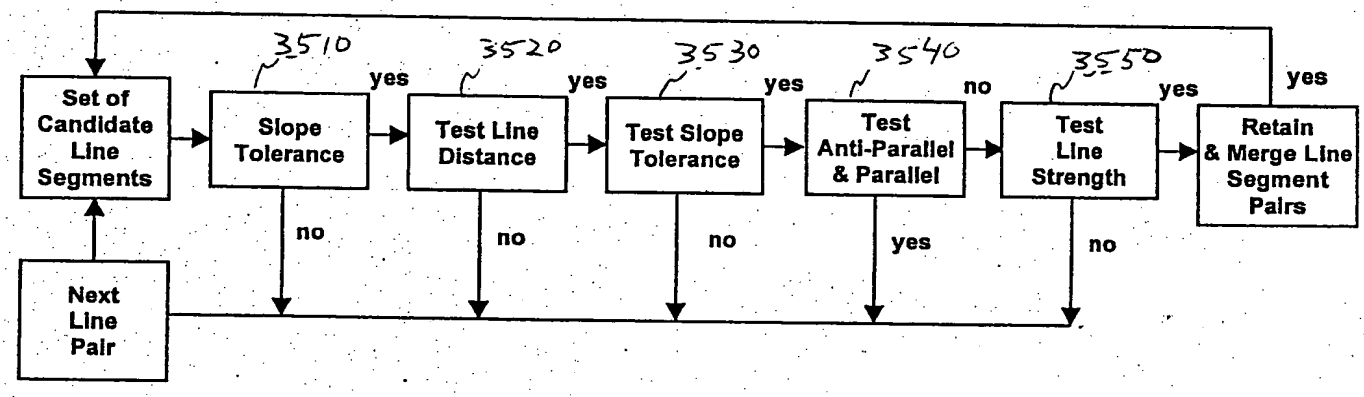


FIG 35

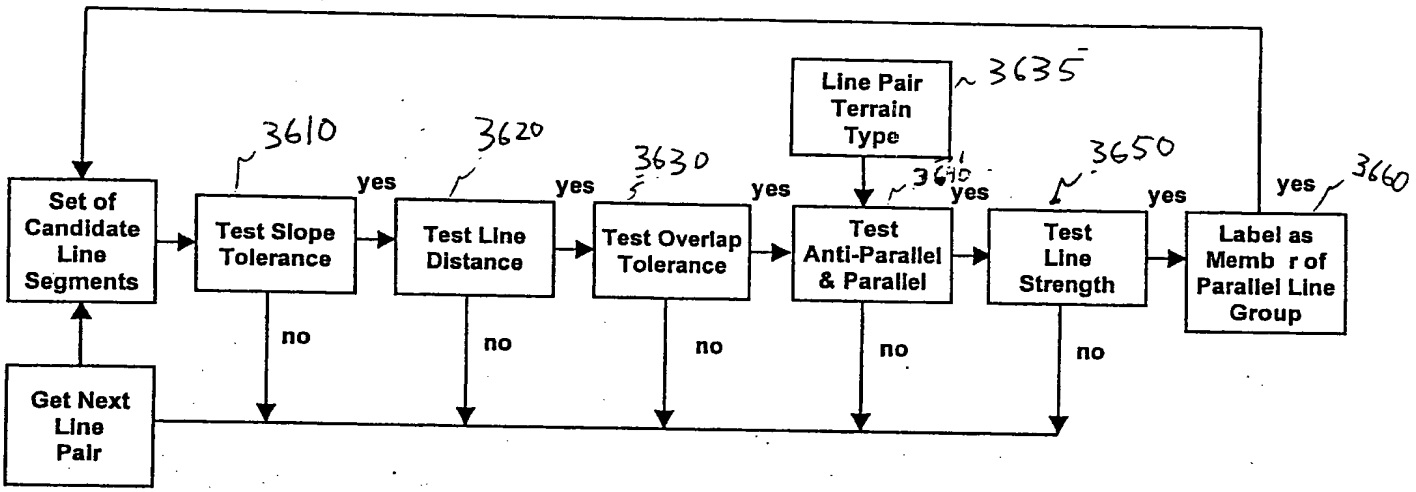

Set of Candidate Line Segments
Get Next Line Pair
Test Slope Tolerance
Test Line Distance
Test Overlap Tolerance
Line Pair Terrain Type
Test Anti-Parallel & Parallel
Test Line Strength
Label as Memb r of Parallel Line Group
3610
3620
3630
3635
3650
3660
yes
no

FIG 3.6

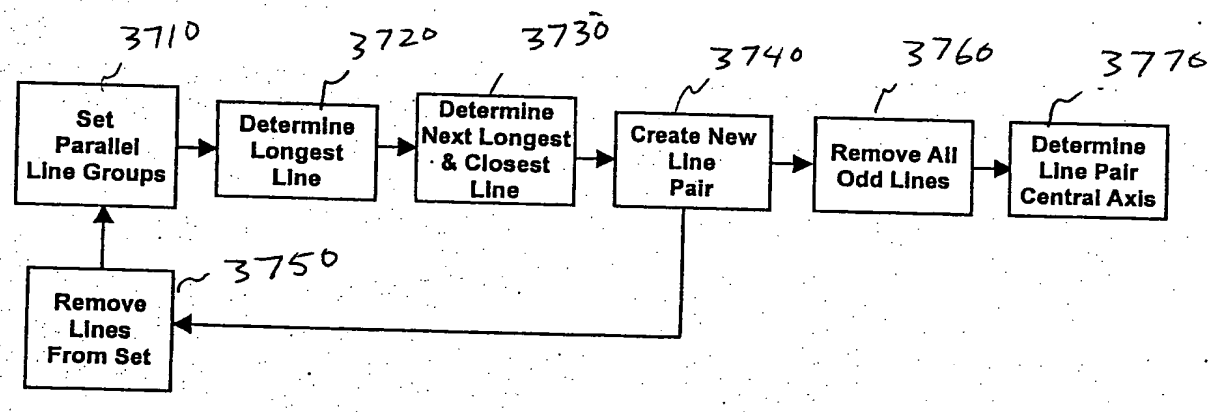

Set Parallel Line Groups
Determine Longest Line
Determine Next Longest & Closest Line
Create New Line Pair
Remove All Odd Lines
Determine Line Pair Central Axis
Remove Lines From Set
3710
3720
3730
3740
3750
3760
3770

FIG 37

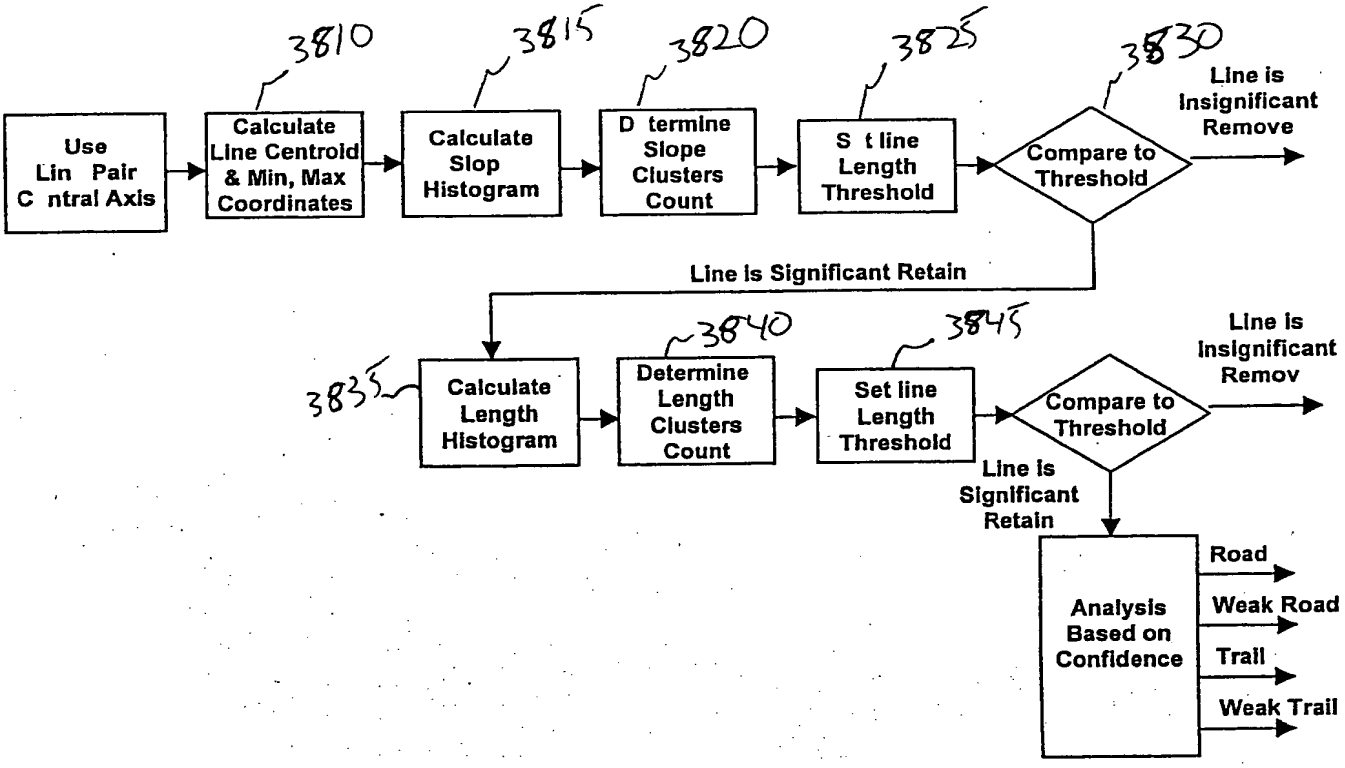

3810
3815
3820
3825
3830
Use Lin Pair C ntral Axis
Calculate Line Centroid & Min, Max Coordinates
Calculate Slop Histogram
D termine Slope Clusters Count
S t line Length Threshold
Compare to Threshold
Line is Insignificant Remove
Line is Significant Retain
3835
3840
3845
Calculate Length Histogram
Determine Length Clusters Count
Set line Length Threshold
Compare to Threshold
Line is Insignificant Remov
Line is Significant Retain
Analysis Based on Confidence
Road
Weak Road
Trail
Weak Trail

FIG 38

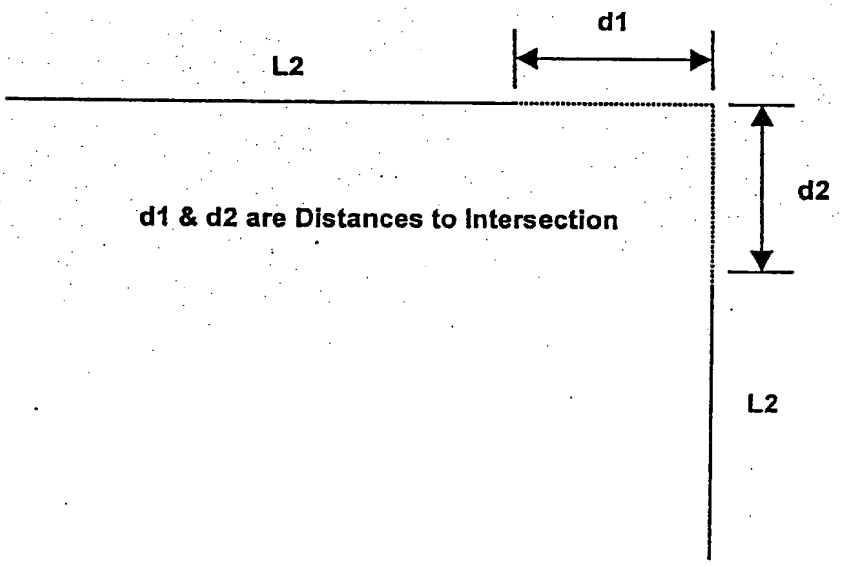

d1
L2
d2
d1 & d2 are Distances to Intersection
L2

FIG 39

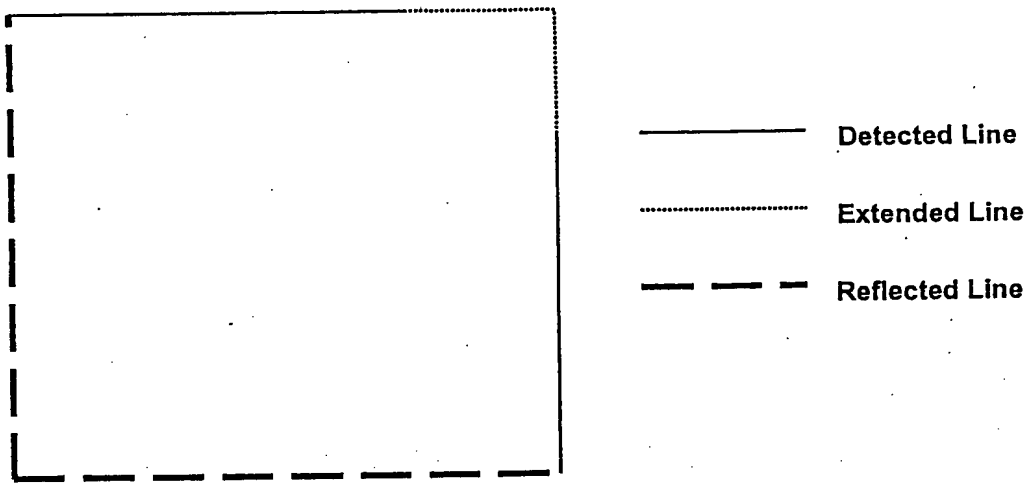


FIG. 40

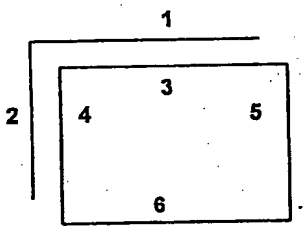


FIG 41A

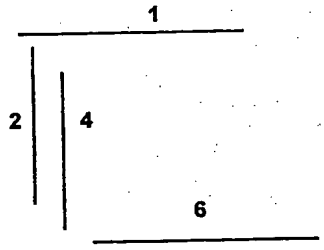


FIG 41B

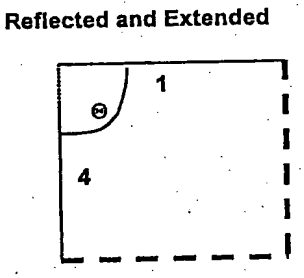


FIG 41C

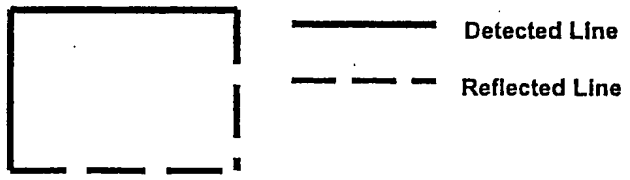


FIG 42A

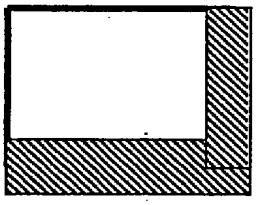


FIG 42B

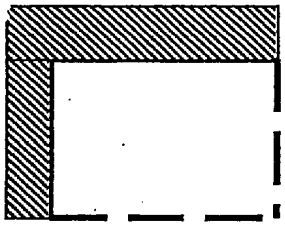


FIG 42C

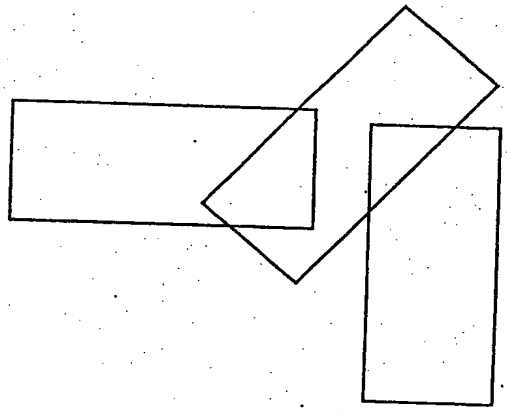


FIG 43A

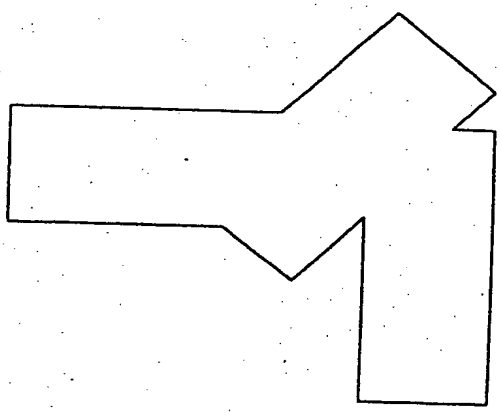


FIG 43B

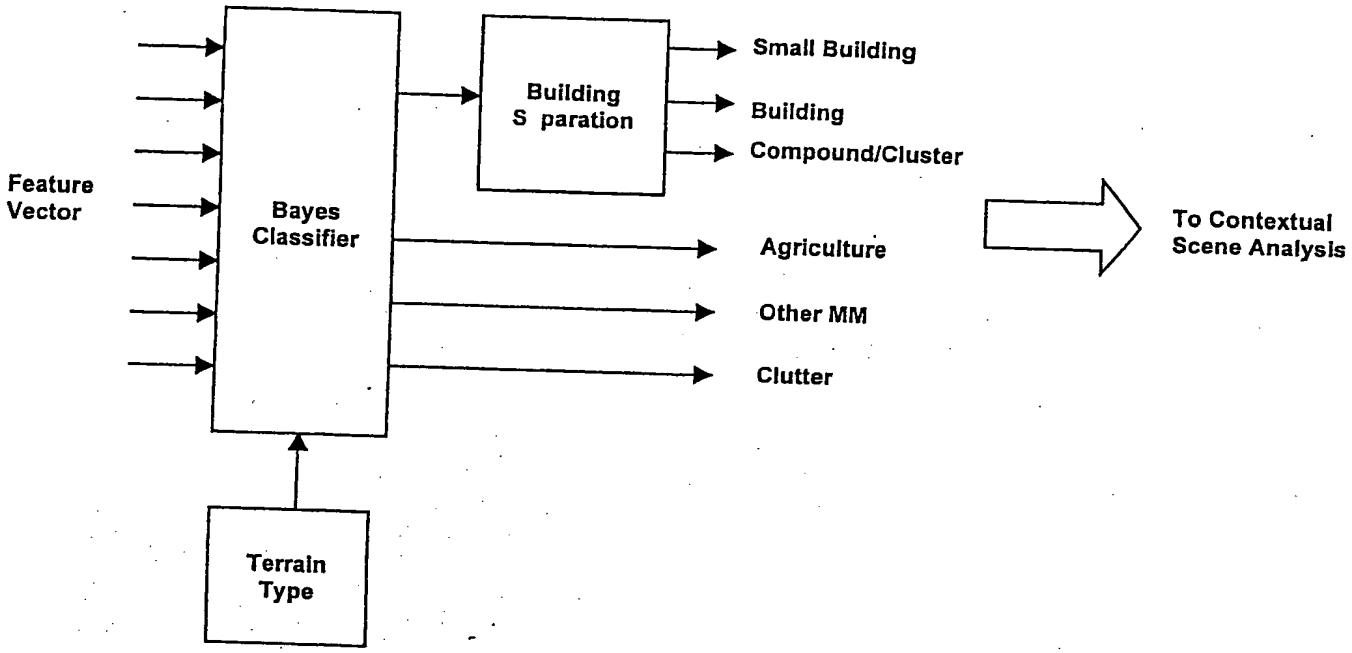

Feature Vector
Bayes Classifier
Building S paration
Small Building
Building
Compound/Cluster
Agriculture
Other MM
Clutter
To Contextual Scene Analysis
Terrain Type

FIG 44

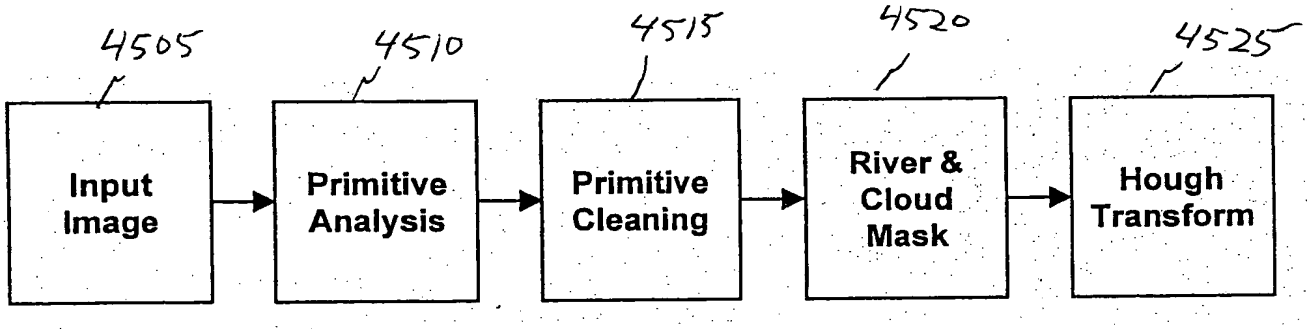

4505
4510
4515
4520
4525
Input Image
Primitive Analysis
Primitive Cleaning
River & Cloud Mask
Hough Transform

FIG 45

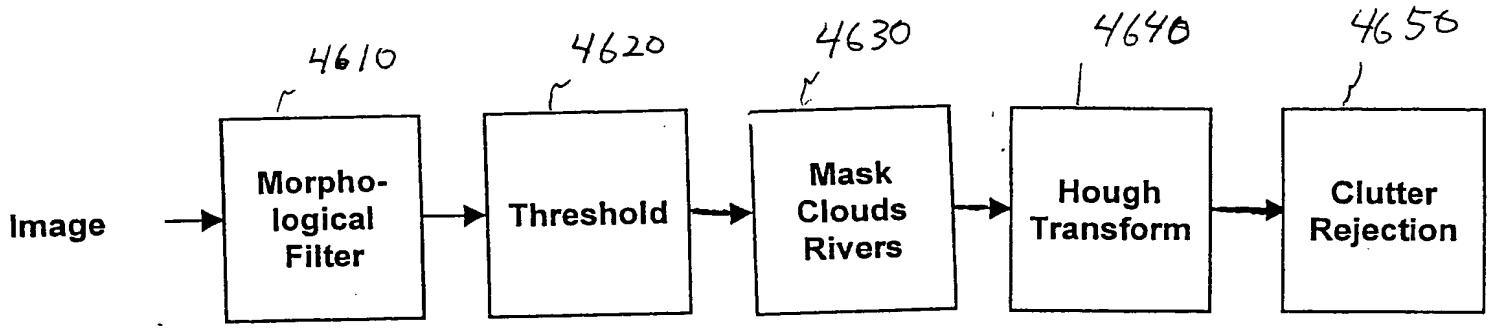


FIG 46

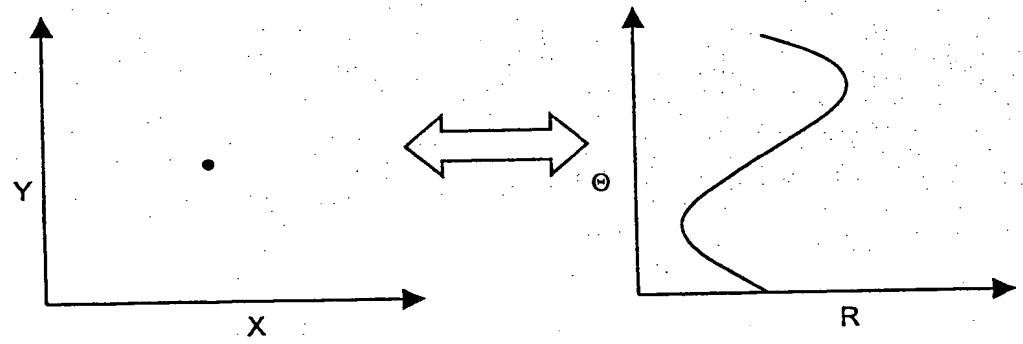


FIG 47A

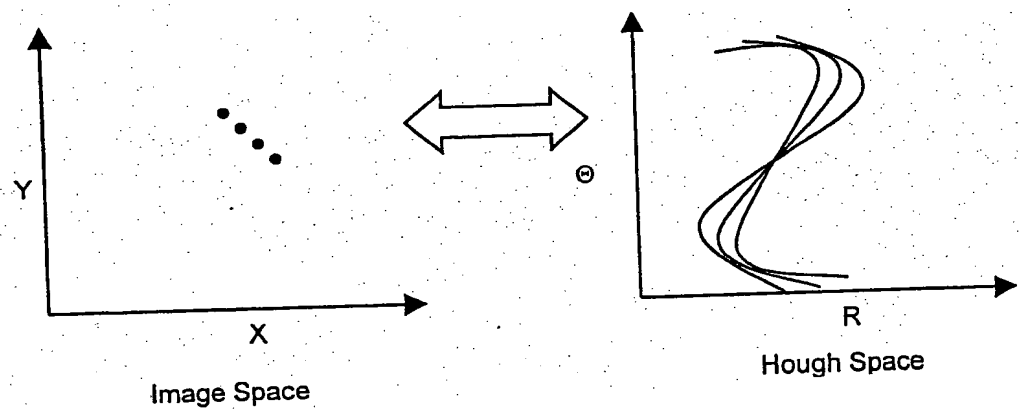


FIG 47B

$$R = x * \cos(\Phi) + y * \sin(\Phi)$$

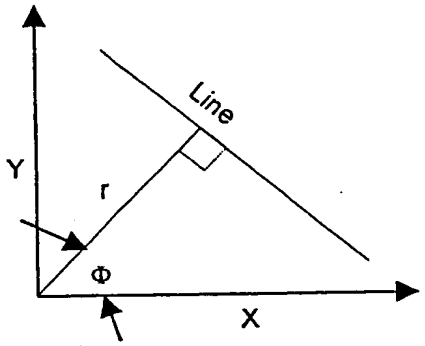


Image Space

FIG 48

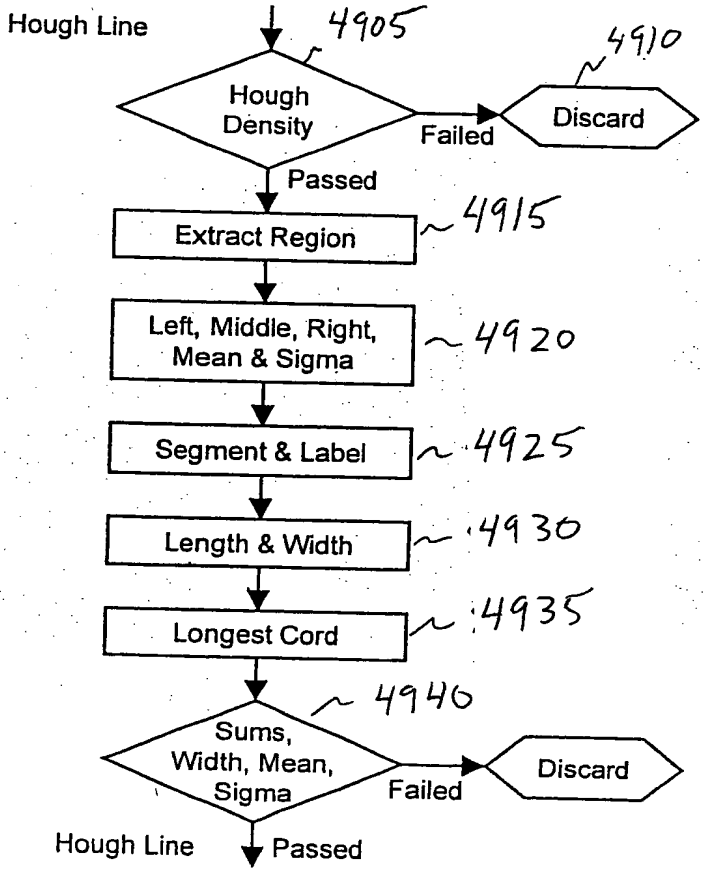


FIG 49

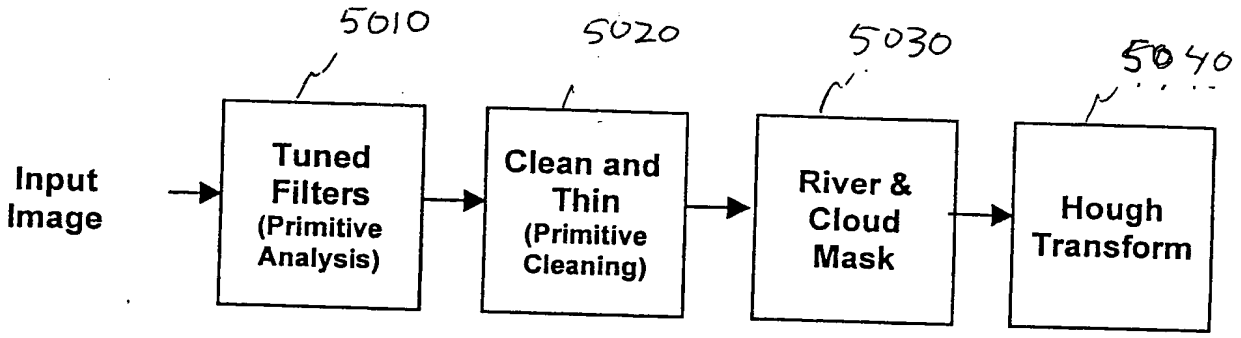


FIG 50

A1	0	B1	0	C1
A2	0	B2	0	C2
A3	0	B3	0	C3
A4	0	B4	0	C4
A5	0	B5	0	C5
A6	0	B6	0	C6
A7	0	B7	0	C7
A8	0	B8	0	C8
A9	0	B9	0	C9
A10	0	B10	0	C10
A11	0	B11	0	C11
A12	0	B12	0	C12
A13	0	B13	0	C13
A14	0	B14	0	C14
A15	0	B15	0	C15

$$B_8 = 2 \times \sum_{i=1}^{15} B_i - \left(\sum_{i=1}^{15} A_i + \sum_{i=1}^{15} C_i \right)$$

FIG 51

A1	A2	A3	A4	A5
A16	B1	B2	B3	A6
A15	B4	B5	B6	A7
A14	B7	B8	B9	A8
A13	A12	A11	A10	A9

FIG 52

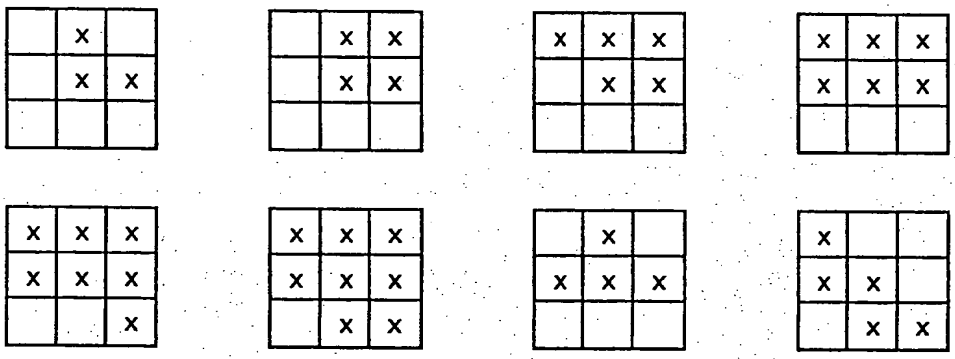


FIG 53

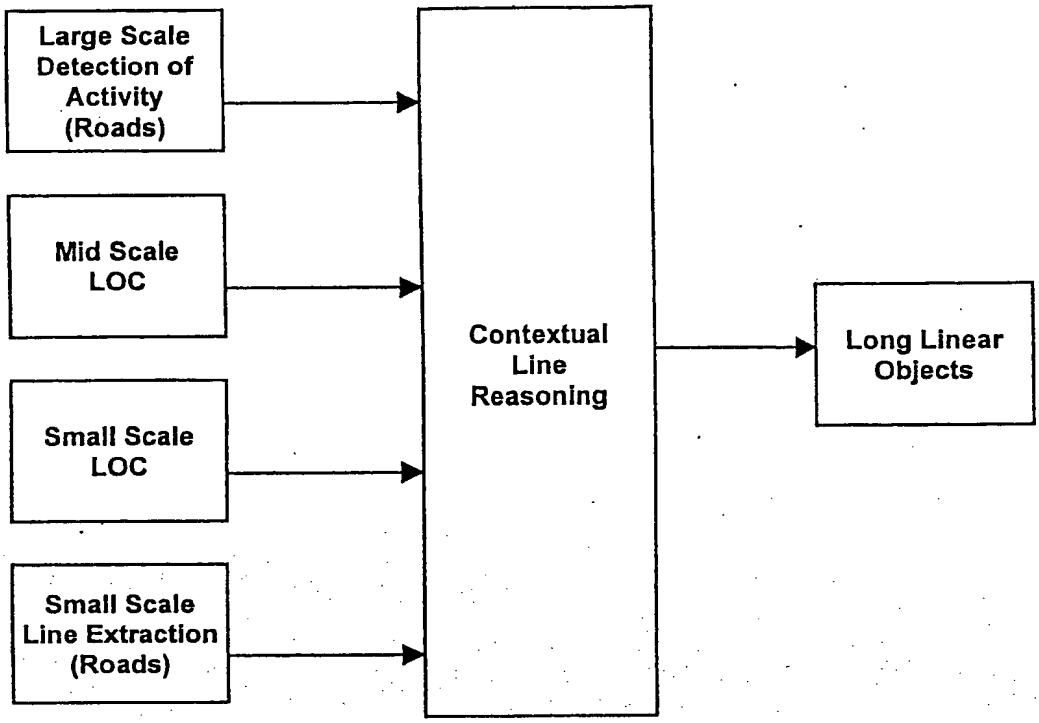

Large Scale Detection of Activity (Roads)
Mid Scale LOC
Small Scale LOC
Small Scale Line Extraction (Roads)
Contextual Line Reasoning
Long Linear Objects

FIG 56

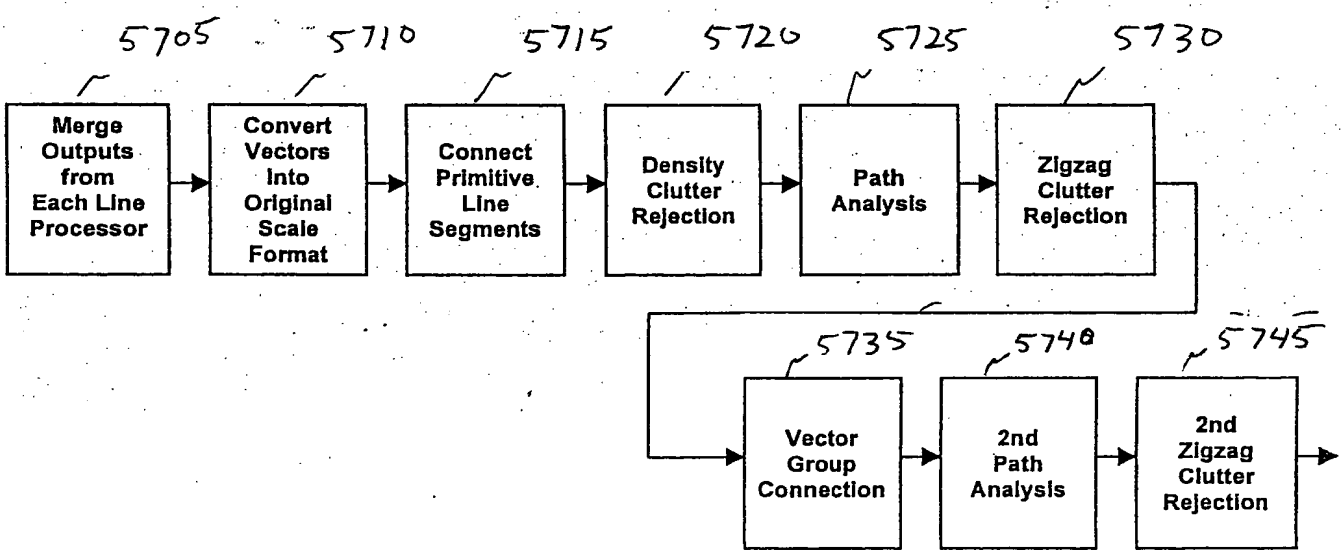

5705
5710
5715
5720
5725
5730
Merge Outputs from Each Line Processor
Convert Vectors Into Original Scale Format
Connect Primitive Line Segments
Density Clutter Rejection
Path Analysis
Zigzag Clutter Rejection
5735
5740
5745
Vector Group Connection
2nd Path Analysis
2nd Zigzag Clutter Rejection

FIG 57

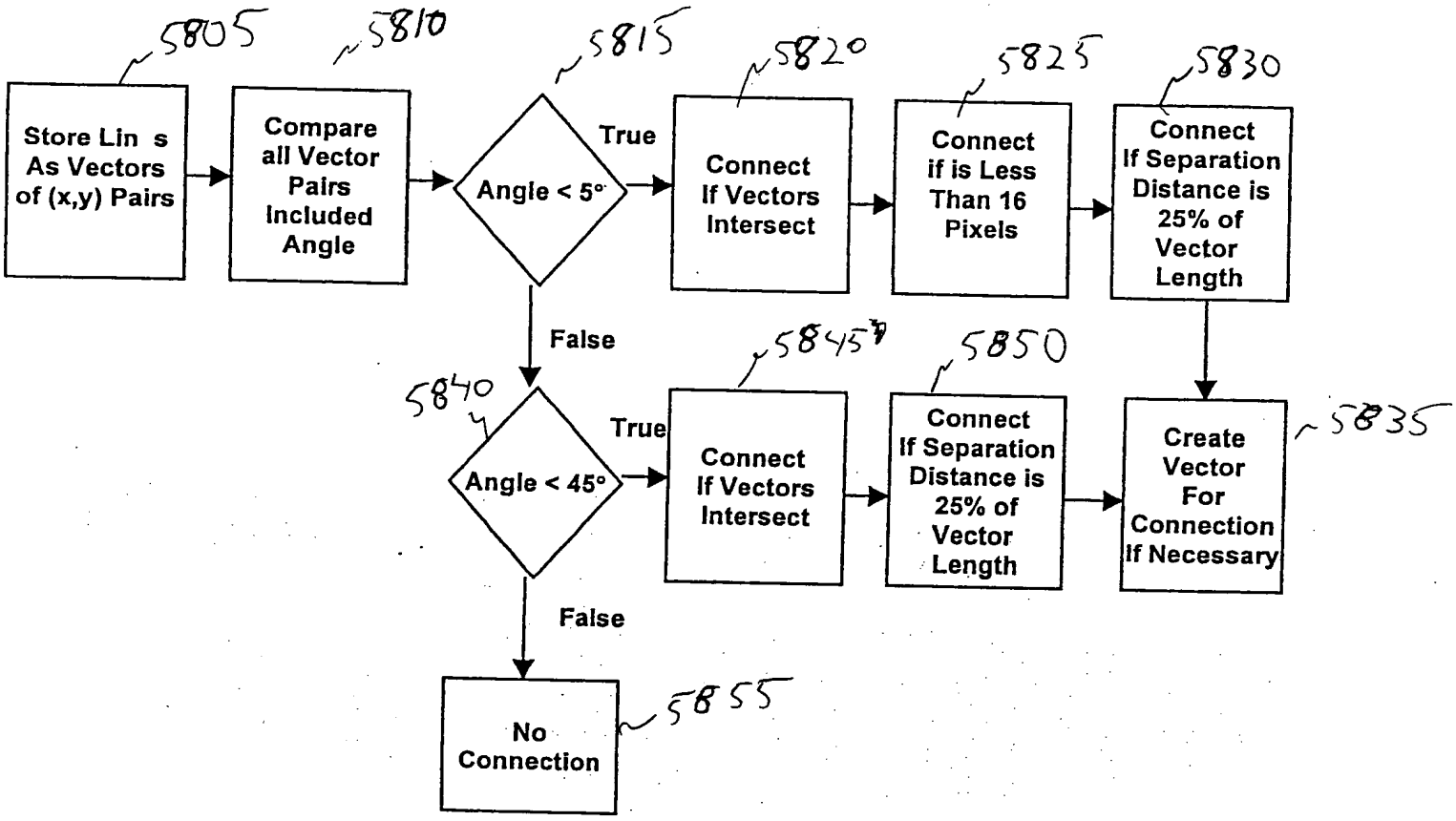


FIG 58

FIG 59A

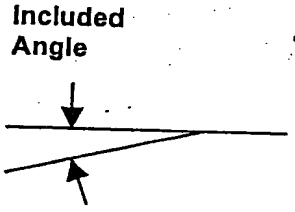


FIG 59B

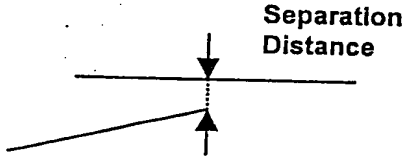


FIG 59C

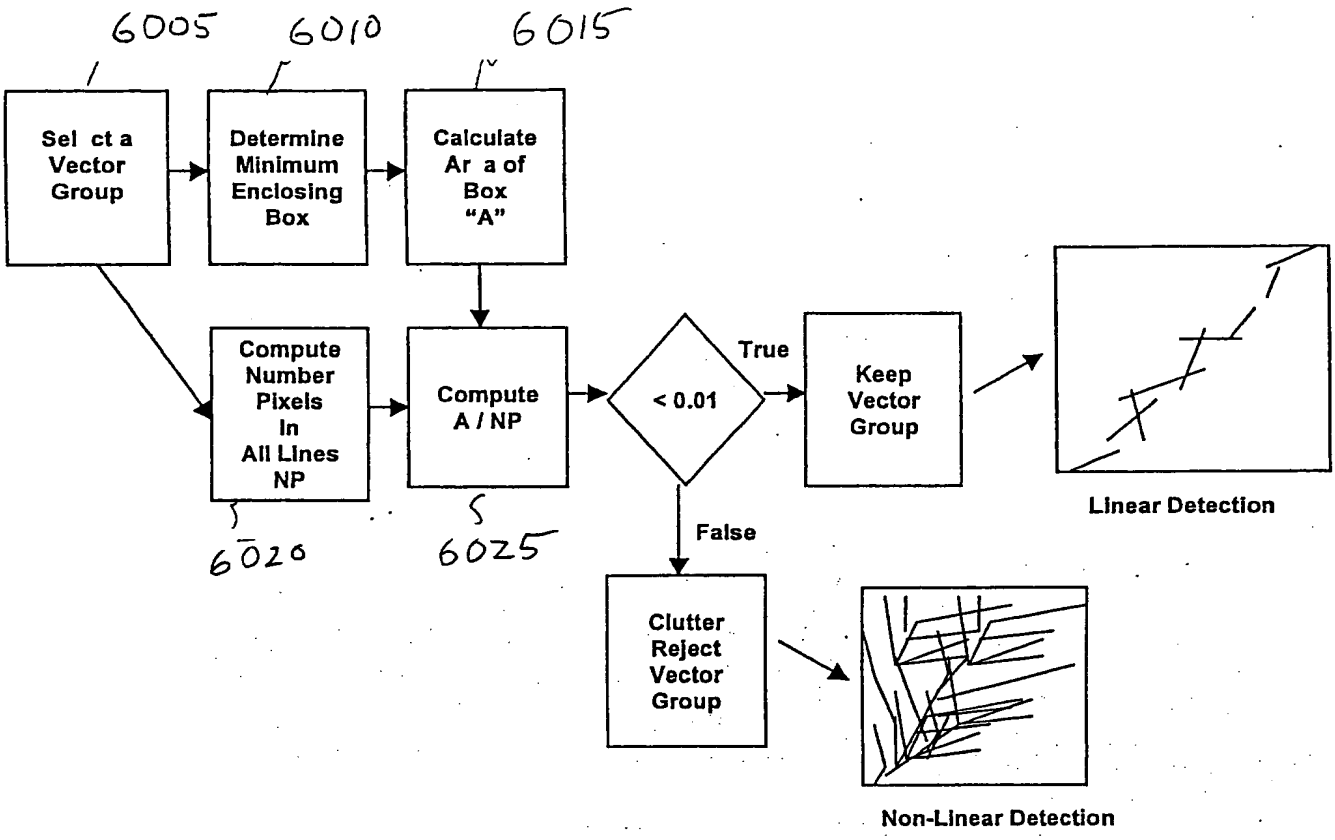


FIG 60

$M^1 = \|m_{ij}^1\|$ Where m_{ij}^1 is the direct distance between node i and j in pixels

$M^2 = \|m_{ij}^2\|$ Where m_{ij}^2 is the direct distance between node i and j in pixels using a most one intermediate node

$M^2 = M^1 \otimes M^1$

$M^4 = M^2 \otimes M^2$

In general the following is true

$M^{n+m} = M^n \otimes M^m$

When $M^t \equiv M^{t+\alpha}$ where α is a positive number all paths are connect

FIG 61

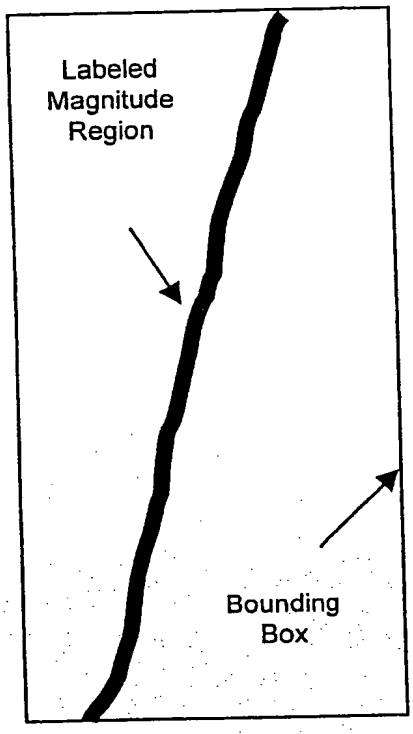

Labeled
Magnitude
Region
Bounding
Box

FIG 54

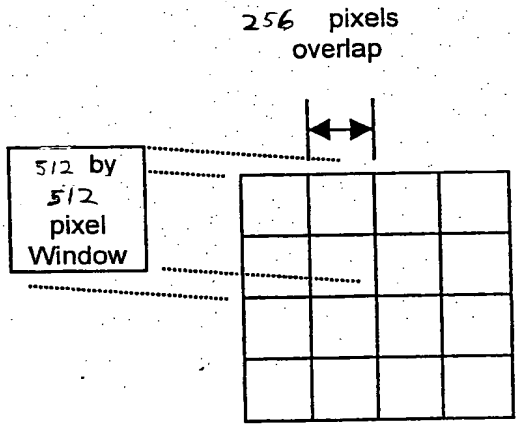

256 pixels
overlap
512 by
512
pixel
Window

FIG 55

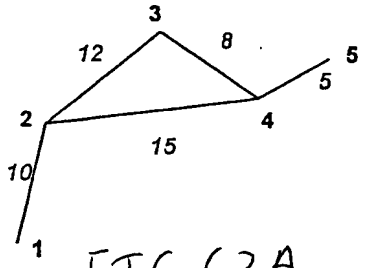


FIG 62A

$$M^1 = \begin{matrix} 0 & 10 & 0 & 0 & 0 \\ x & 0 & 12 & 15 & 0 \\ x & x & 0 & 8 & 0 \\ x & x & x & 0 & 5 \\ x & x & x & x & 0 \end{matrix}$$

FIG 62B

$$M^2 = \begin{matrix} 0 & 10 & 22 & 25 & 0 \\ x & 0 & 12 & 15 & 20 \\ x & x & 0 & 8 & 13 \\ x & x & x & 0 & 5 \\ x & x & x & x & 0 \end{matrix}$$

FIG 62C

$$M^3 = \begin{matrix} 0 & 10 & 22 & 25 & 30 \\ x & 0 & 12 & 15 & 20 \\ x & x & 0 & 8 & 13 \\ x & x & x & 0 & 5 \\ x & x & x & x & 0 \end{matrix}$$

FIG 62D

$M^3 = M^4$

FIG 62E

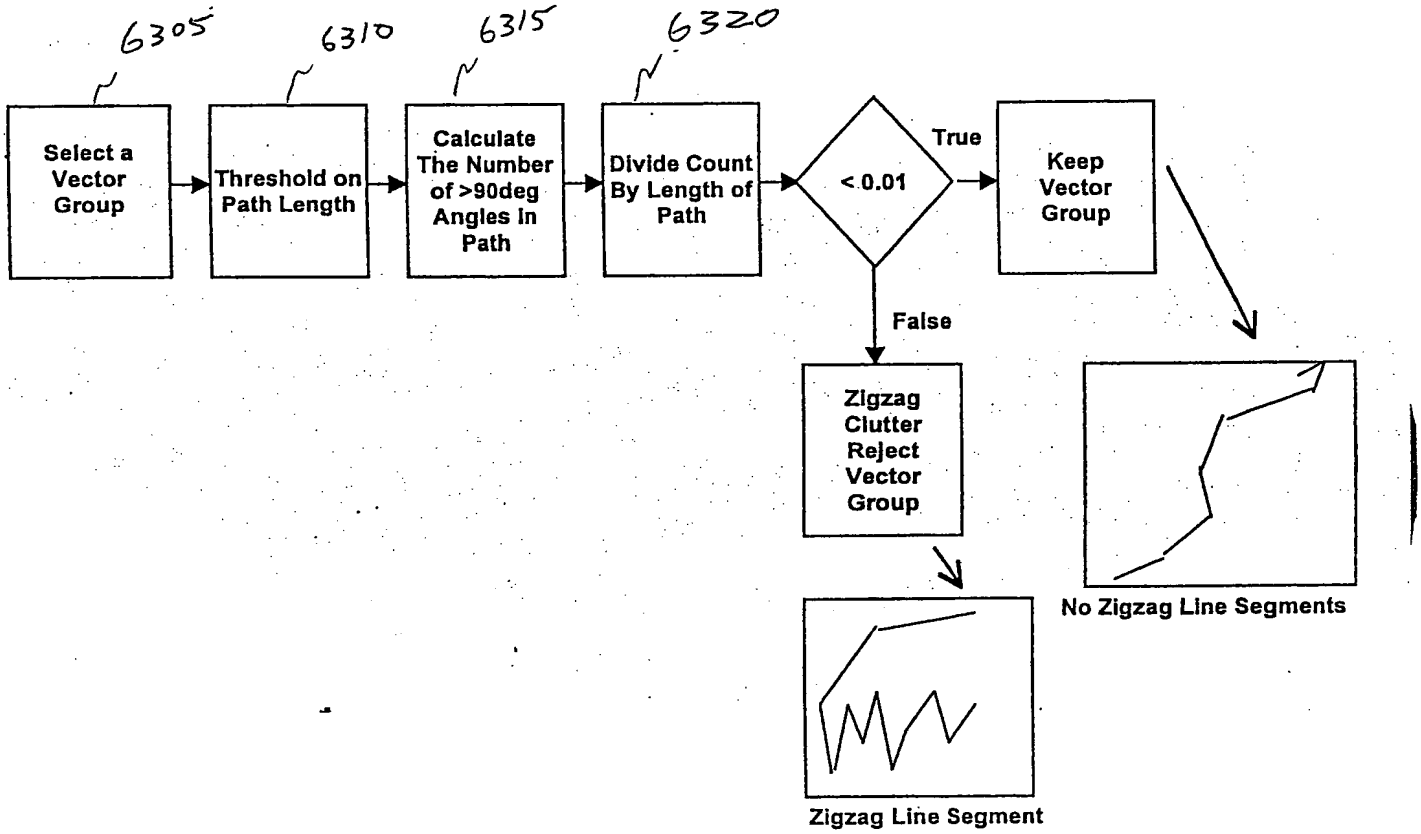


FIG 63

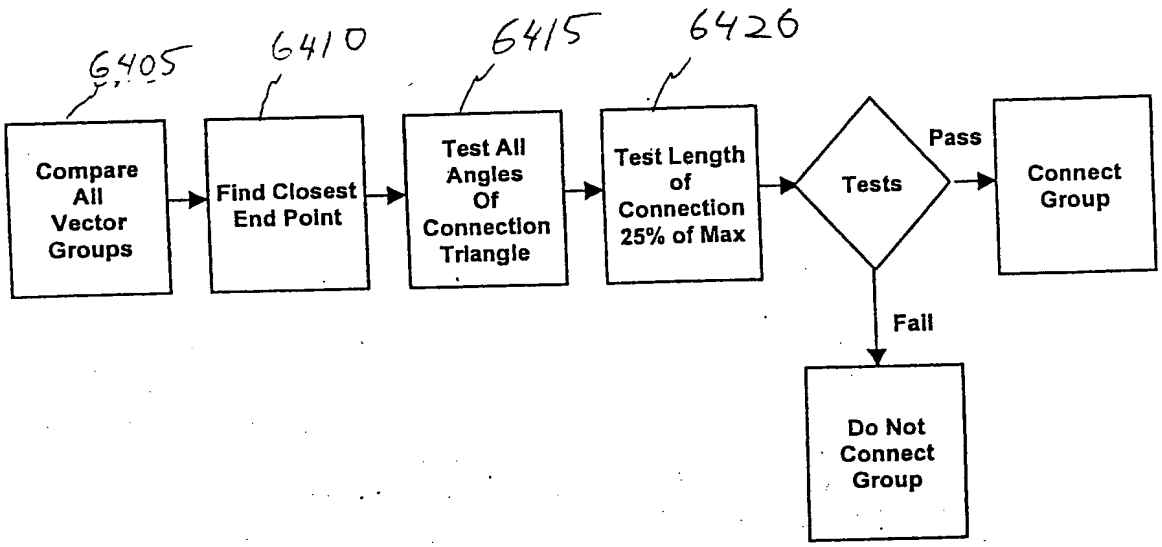

6405
6410
6415
6426
Compare All Vector Groups
Find Closest End Point
Test All Angles Of Connection Triangle
Test Length of Connection 25% of Max
Tests
Pass
Connect Group
Fail
Do Not Connect Group

FIG 64

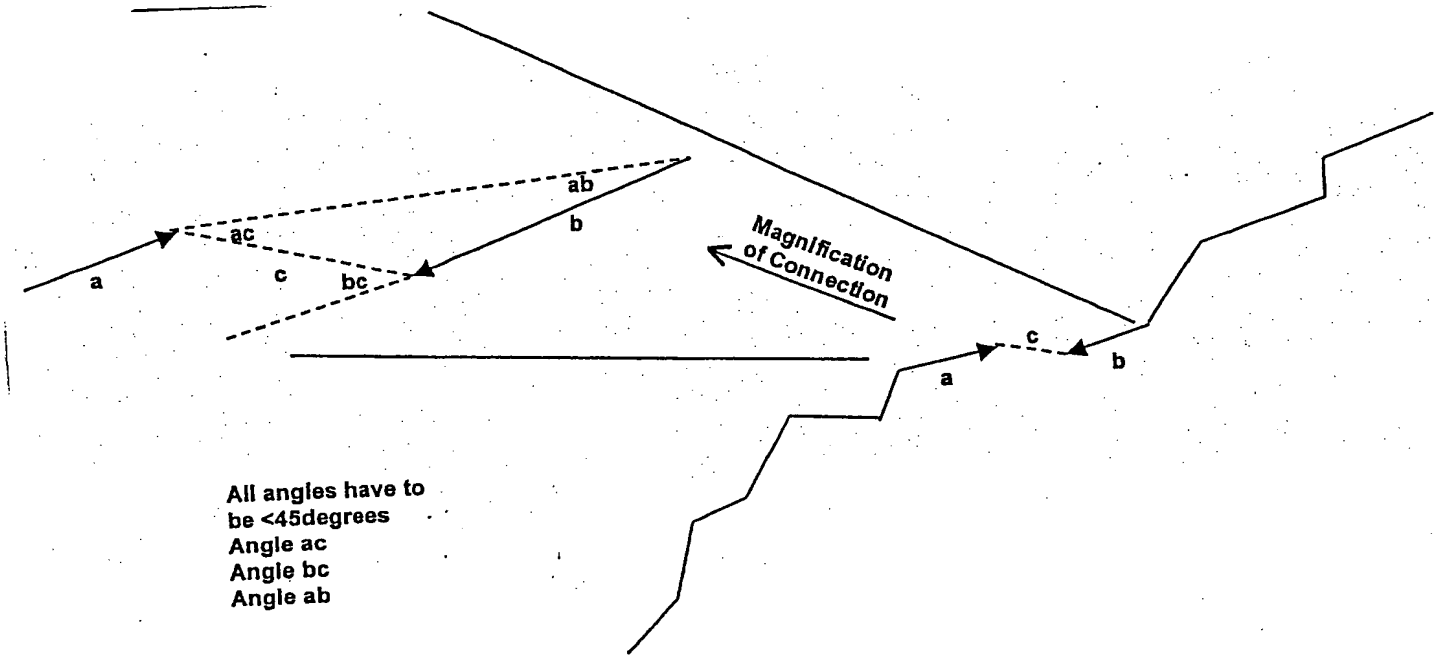

a
ac
c
bc
ab
b
Magnification of Connection
a
c
b
All angles have to be <45degrees
Angle ac
Angle bc
Angle ab

FIG 65

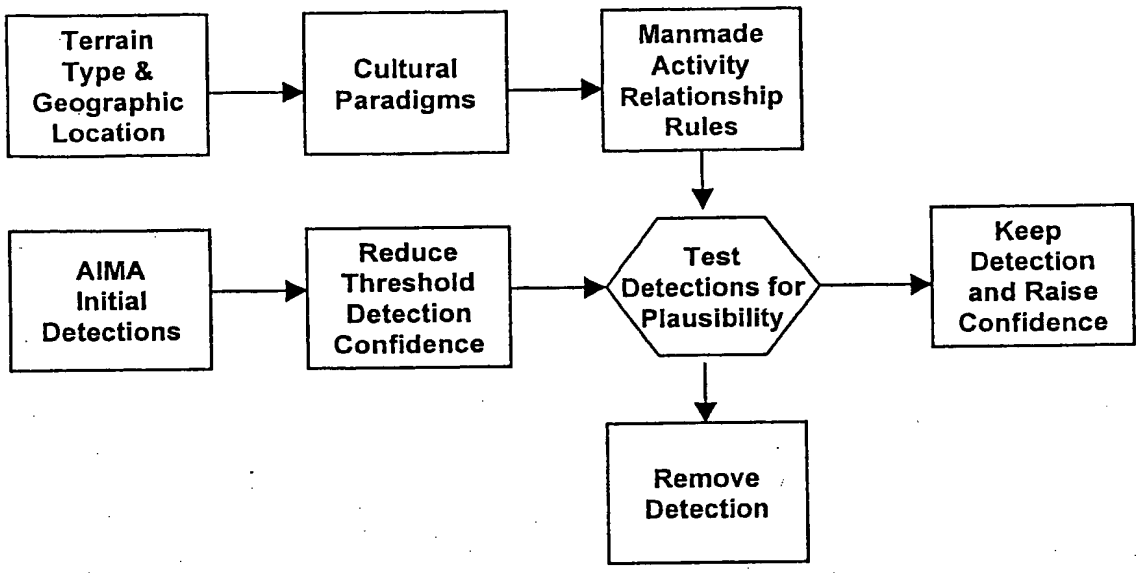

Terrain Type & Geographic Location
Cultural Paradigms
Manmade Activity Relationship Rules
AIMA Initial Detections
Reduce Threshold Detection Confidence
Test Detections for Plausibility
Keep Detection and Raise Confidence
Remove Detection

FIG 66